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ROYAL AERONAUTICAL SOCIETY 1866

Journal

of

THE ROYAL AERONAUTICAL SOCIETY

DECEMBER 1956

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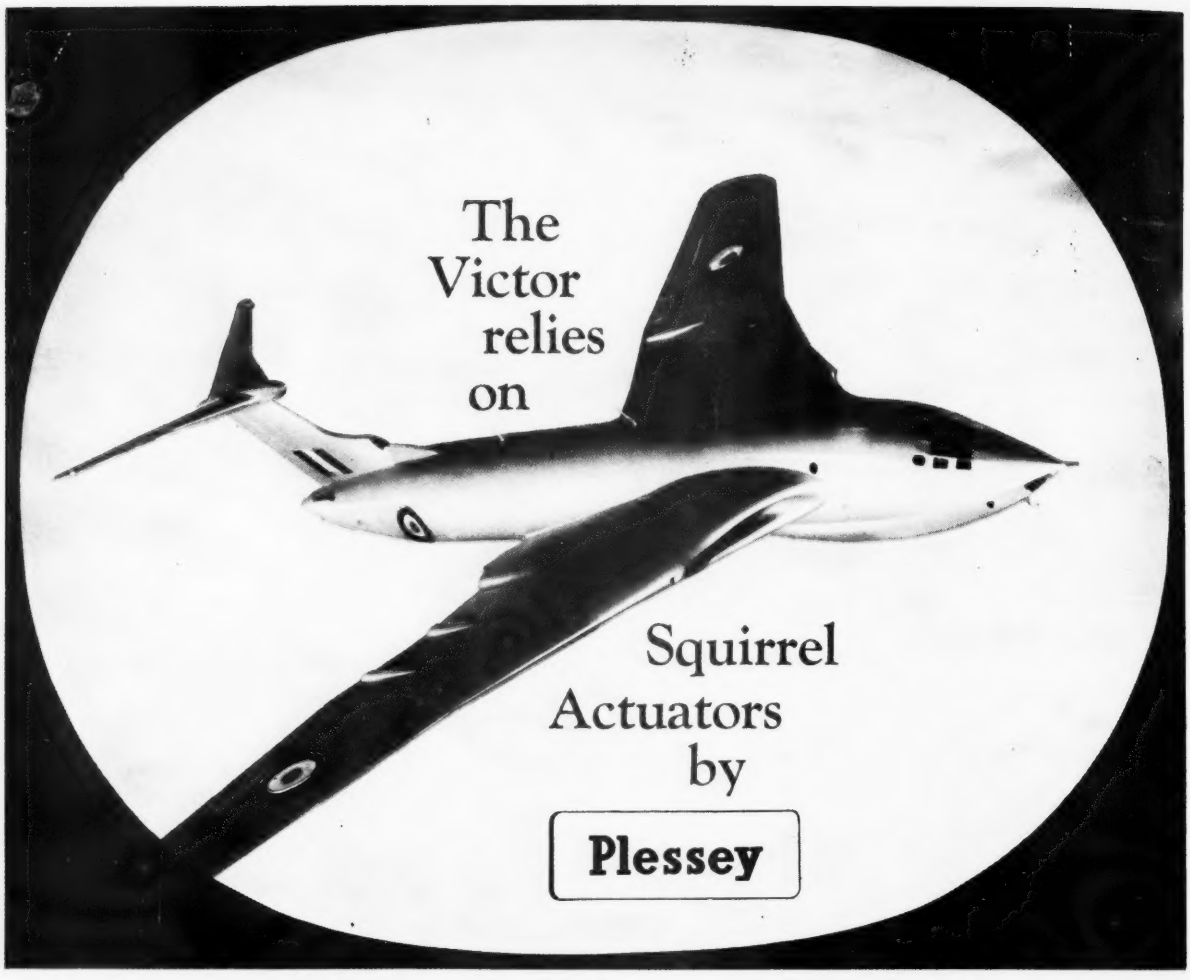

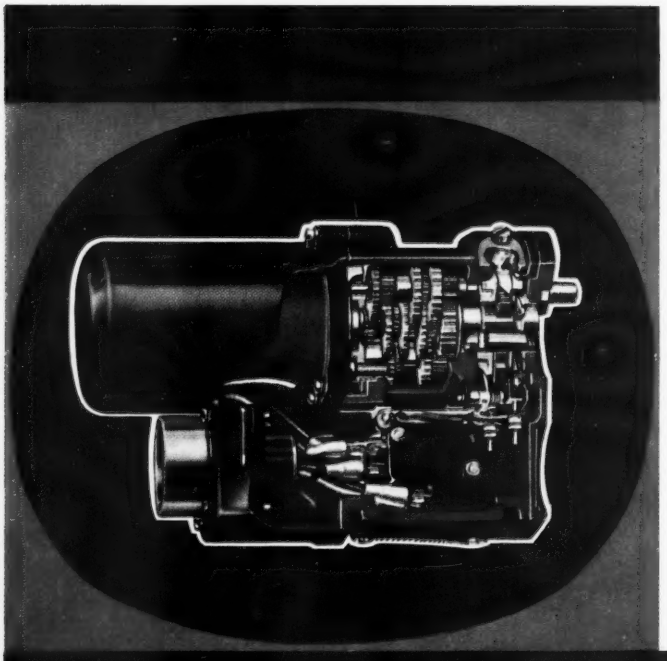

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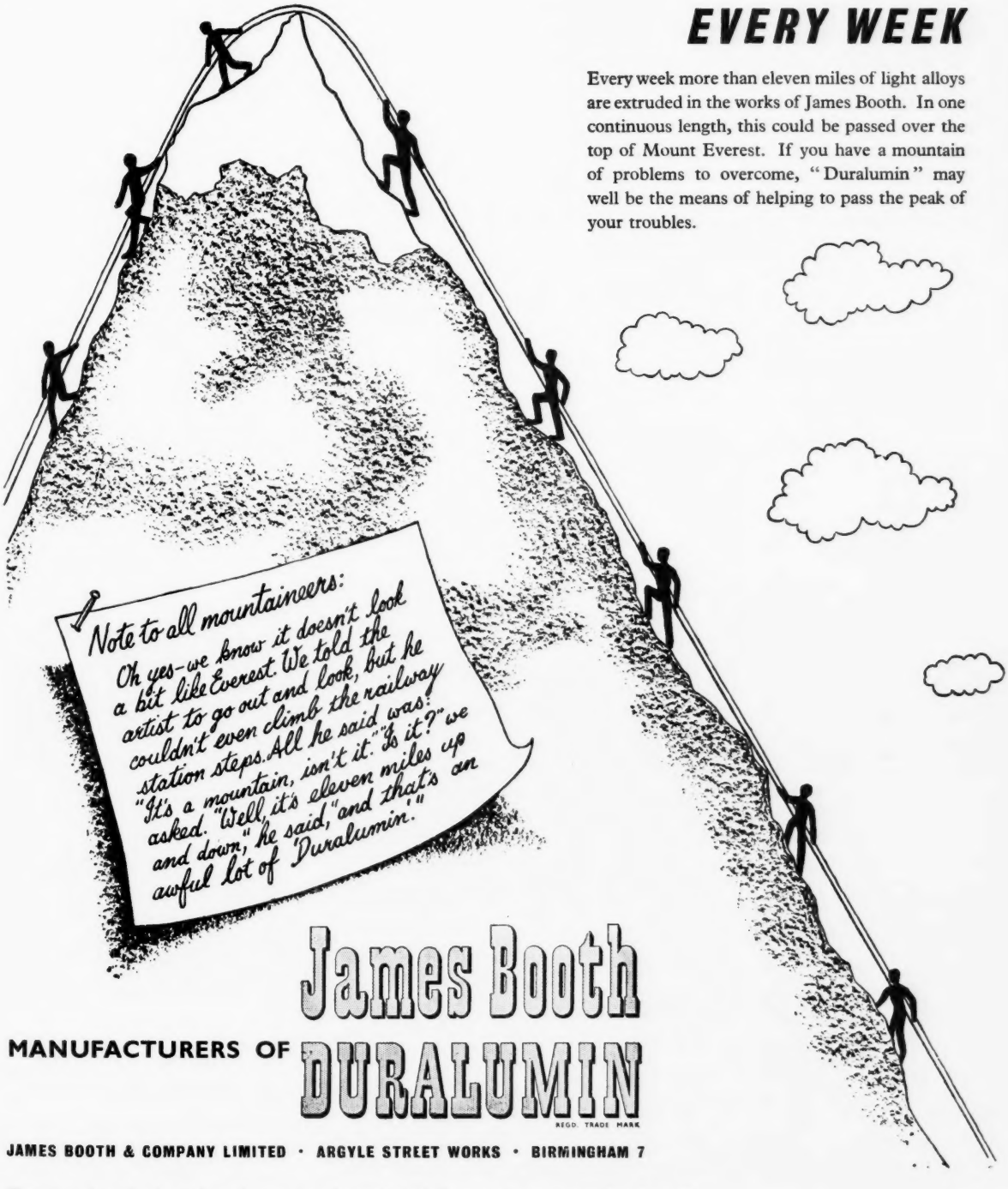
Note to all mountaineers:
Oh yes—we know it doesn't look a bit like Everest. We told the artist to go out and look, but he couldn't even climb the railway station steps. All he said was "It's a mountain, isn't it." "Is it?" we asked. "Well, it's eleven miles up and down," he said, "and that's an awful lot of Duralumin."

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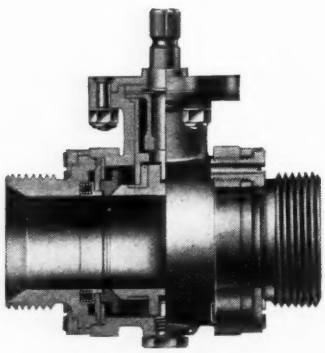

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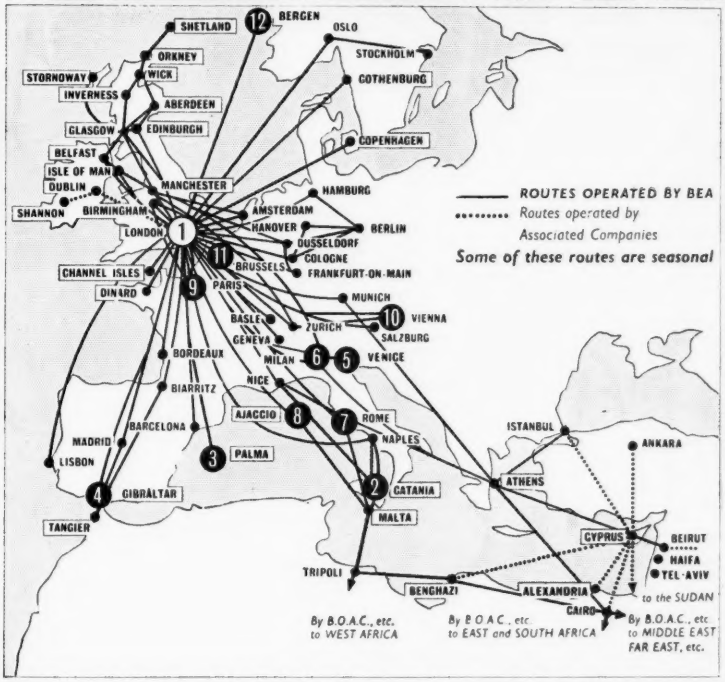

1. *Sir Walter Raleigh (1552-1618) pioneer of the English colonies.*
2. *Garibaldi leading his "Thousand" in Sicily, 1859.*
3. *Chopin and George Sand who went to Majorca in 1838.*
4. *The English fleet under Admiral Rooke capturing Gibraltar, 1704.*
5. *Marco Polo (1254-1324), Venetian explorer, on his way back from China.*
6. *Frederick Barbarossa, German Emperor, entering Milan, 1162.*
7. *The Roman Emperor Caligula (A.D. 37-41), who declared his horse Incitatus a priest and a consul.*
8. *Napoleon, born in Corsica in 1769, on board H.M.S. Bellerophon after his defeat at Waterloo.*
9. *The French Revolution, 1789. Storming of the Bastille.*
10. *Johann Strauss (1825-1899), Viennese composer of the "Blue Danube" and many other waltzes.*
11. *The Duke of Wellington at the Battle of Waterloo (1815).*
12. *Amundsen, Norwegian explorer, on his way to the South Pole (1911).*

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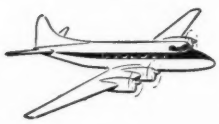

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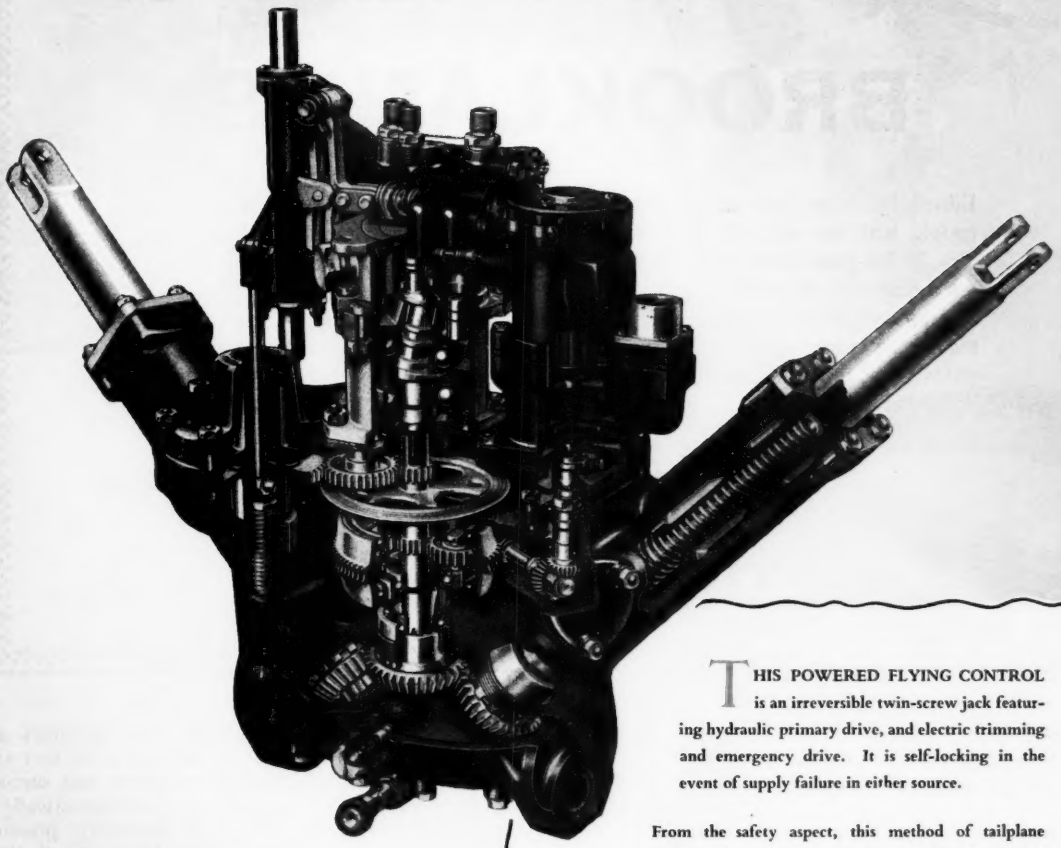

THIS POWERED FLYING CONTROL is an irreversible twin-screw jack featuring hydraulic primary drive, and electric trimming and emergency drive. It is self-locking in the event of supply failure in either source.

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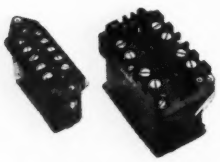

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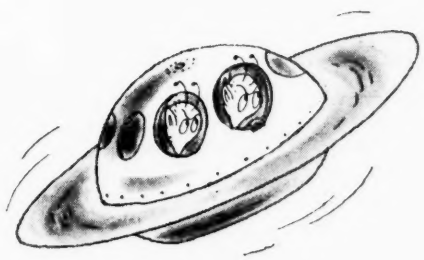

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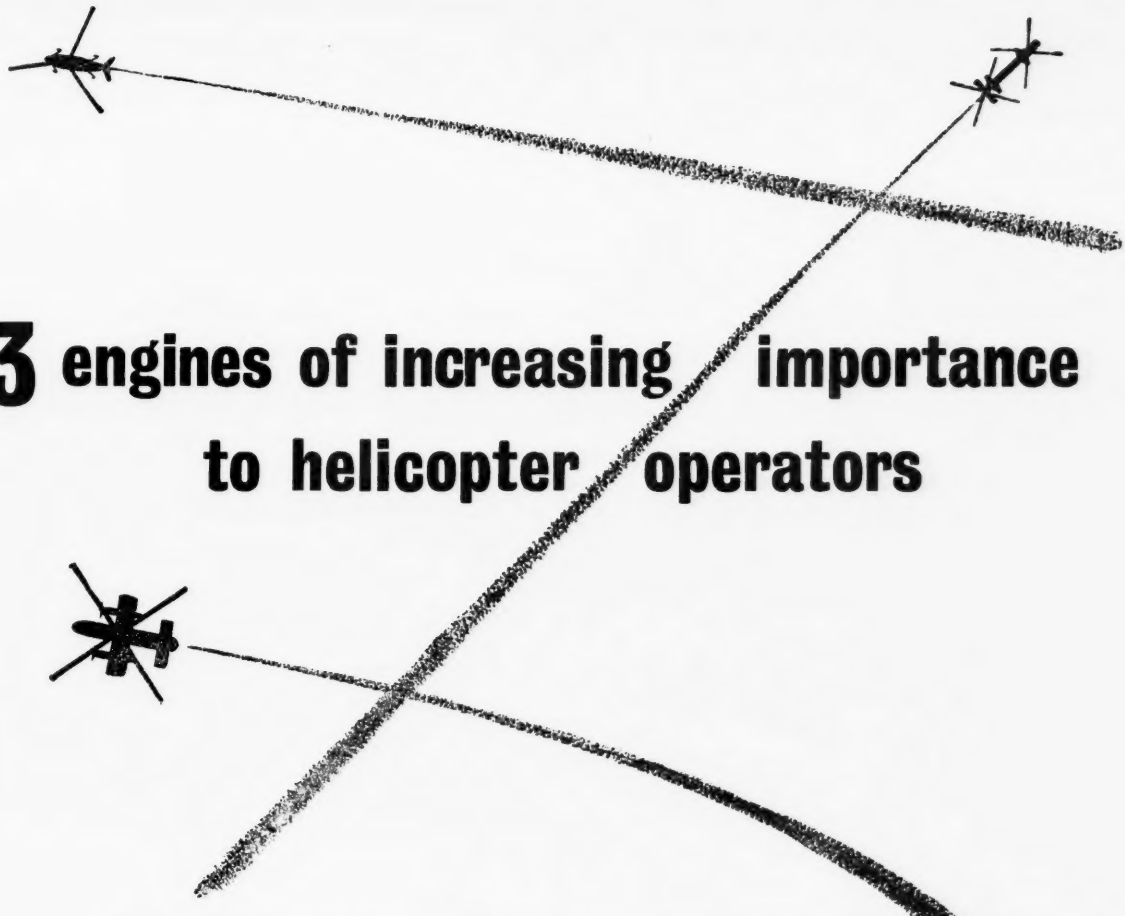

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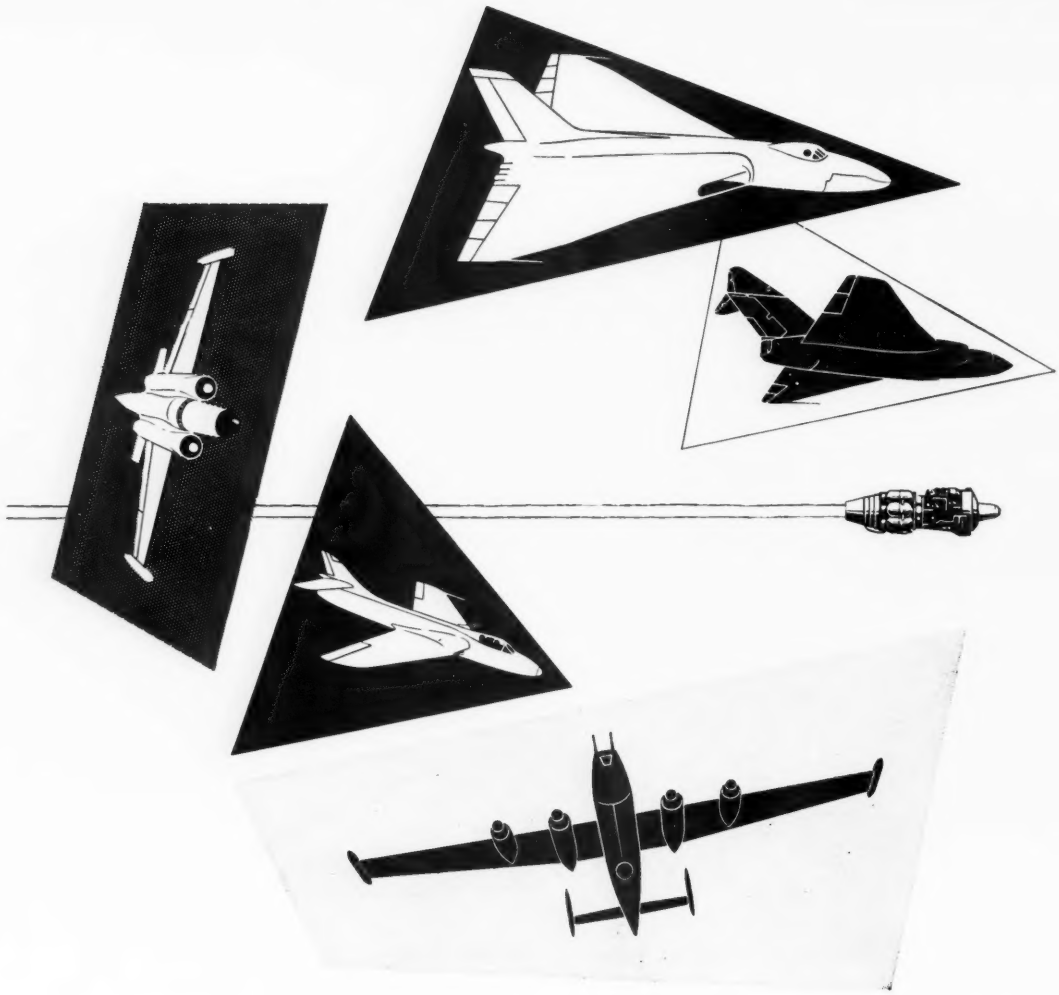

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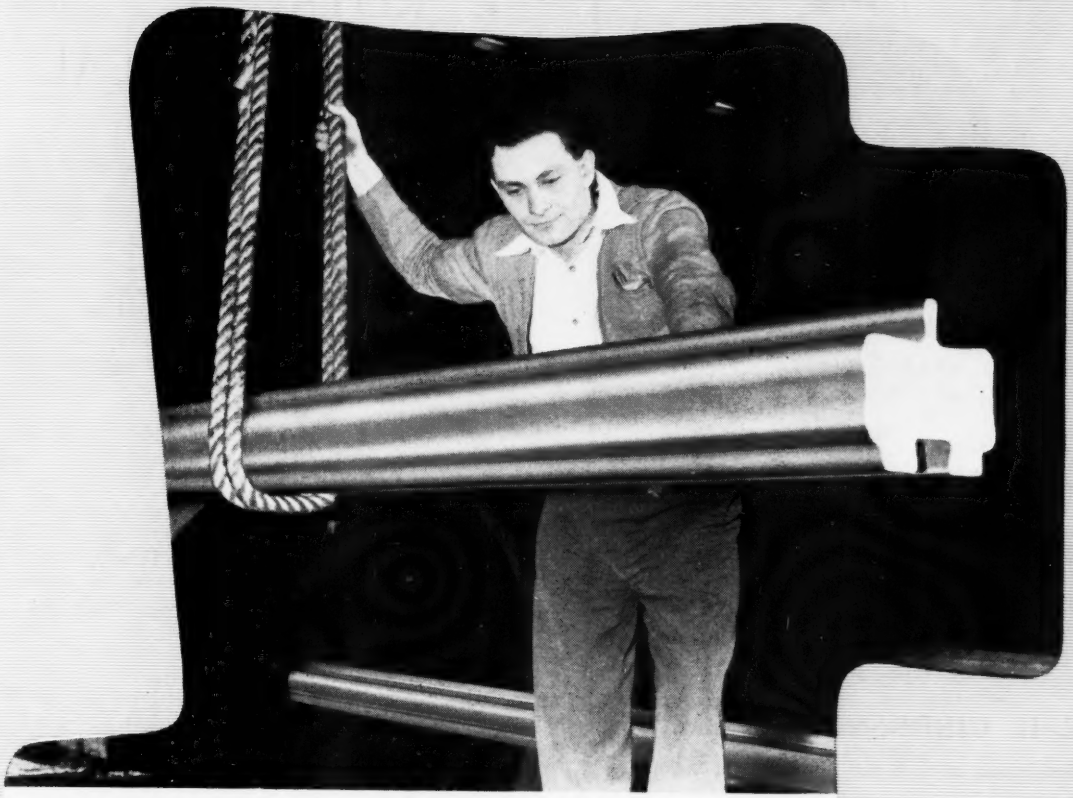

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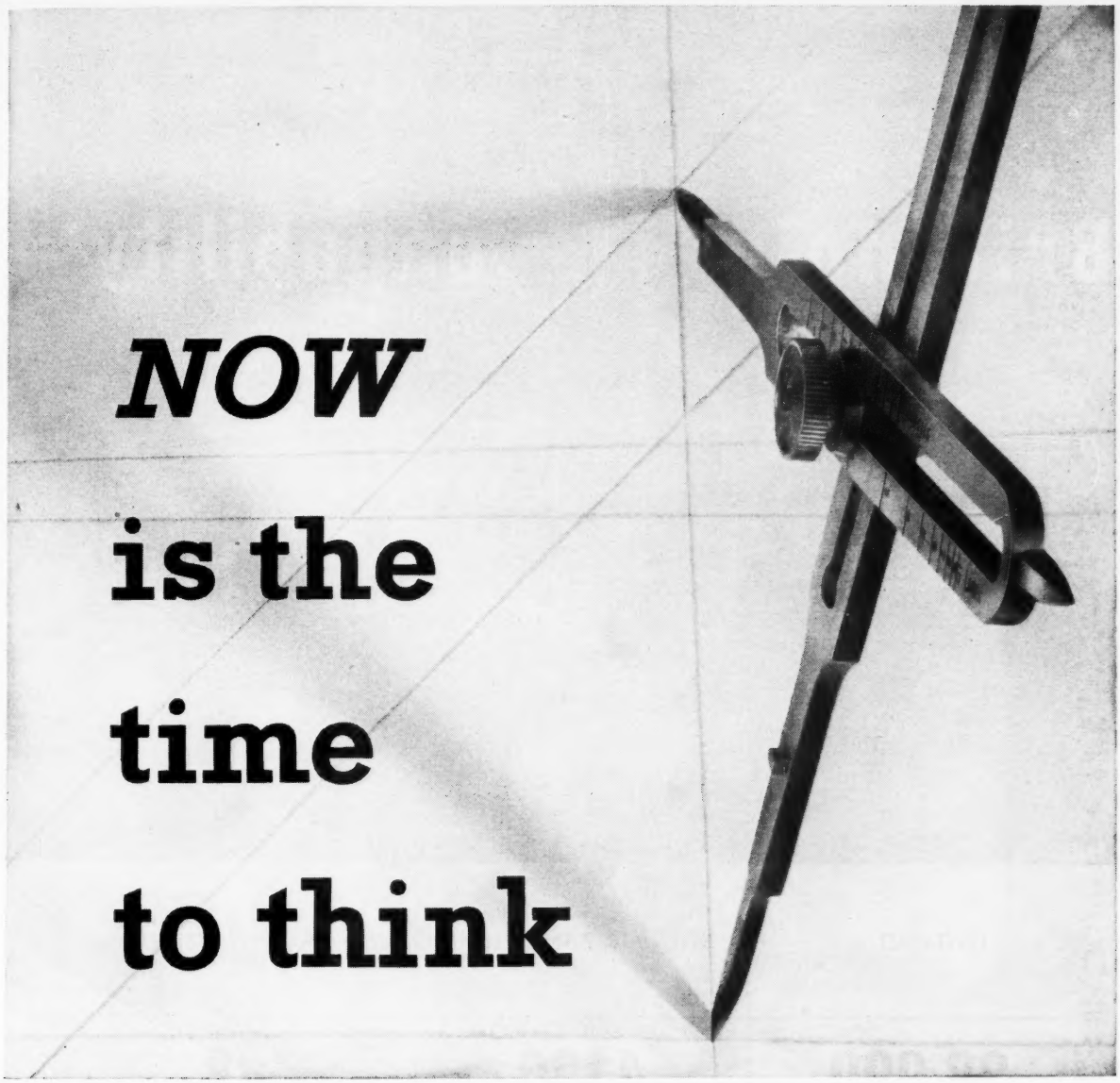

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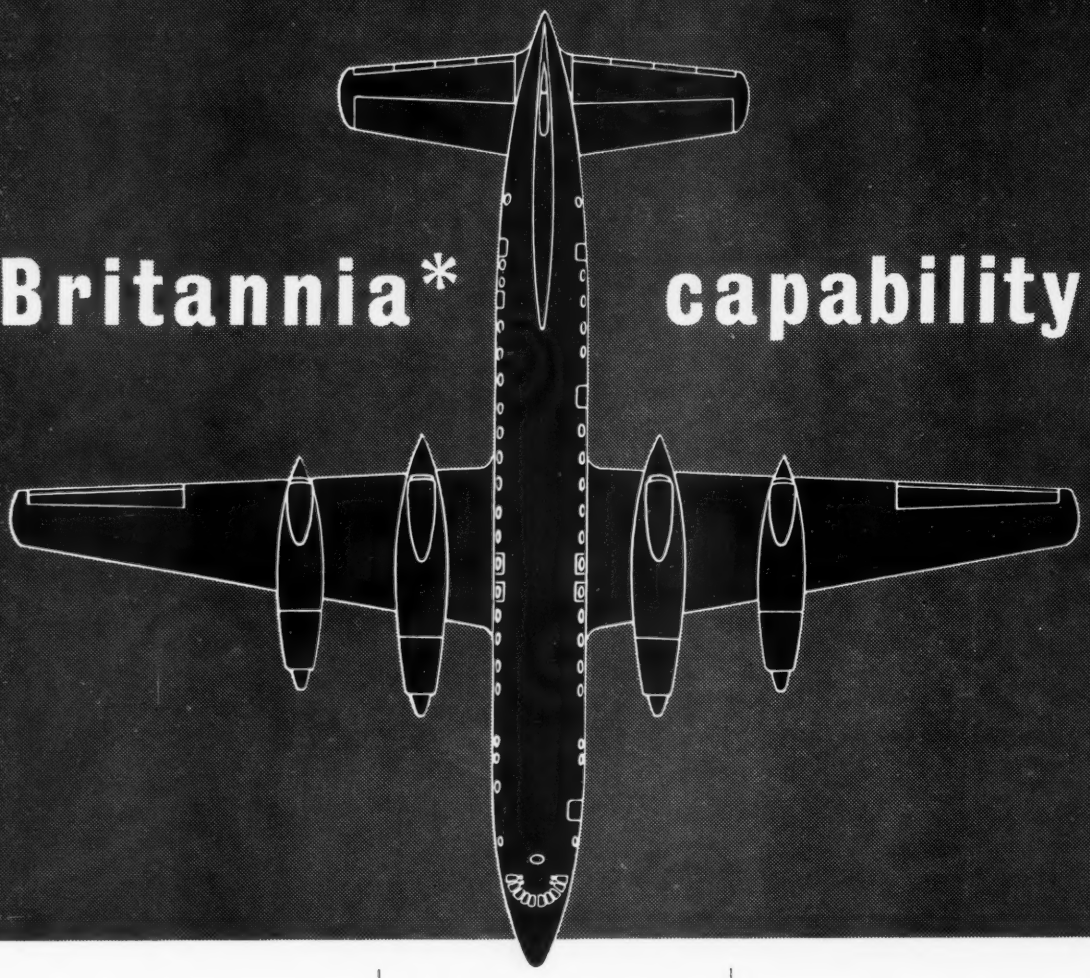

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Above: Photograph of the navigating table inverted to show the resistance welding of the double corrugated skin.

Right: Showing the many intricate compartments of the table where resistance welding is used to great advantage.

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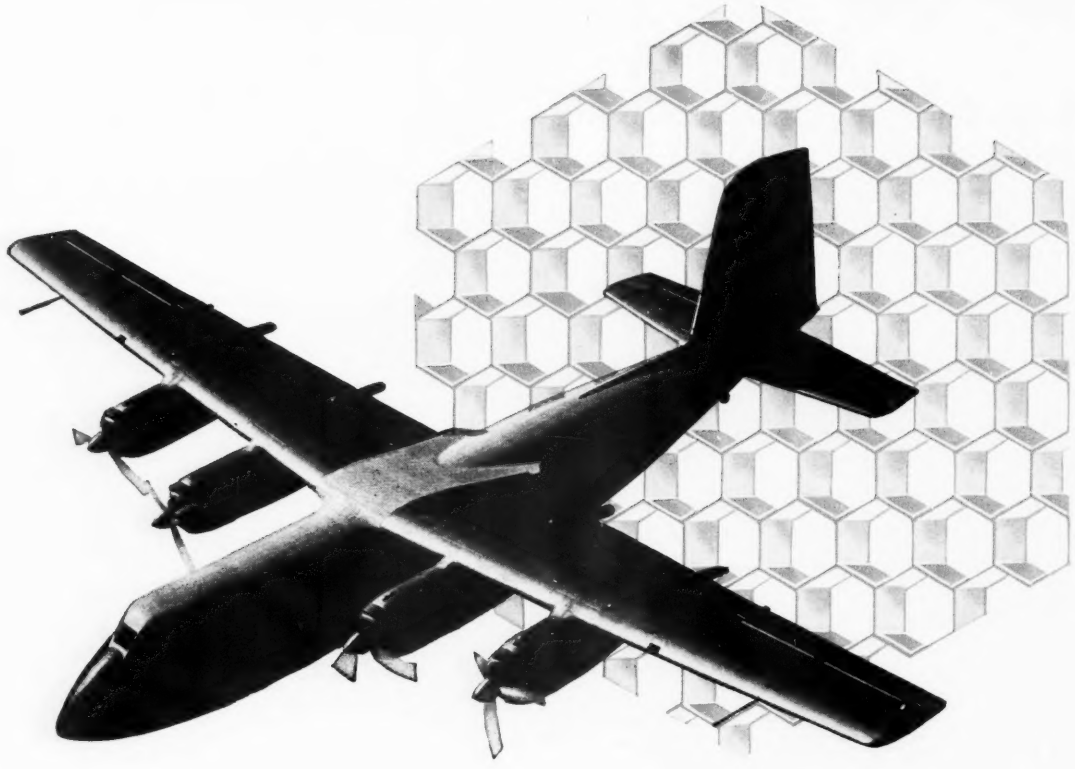
Honeycomb



for the Handley Page 'Herald'

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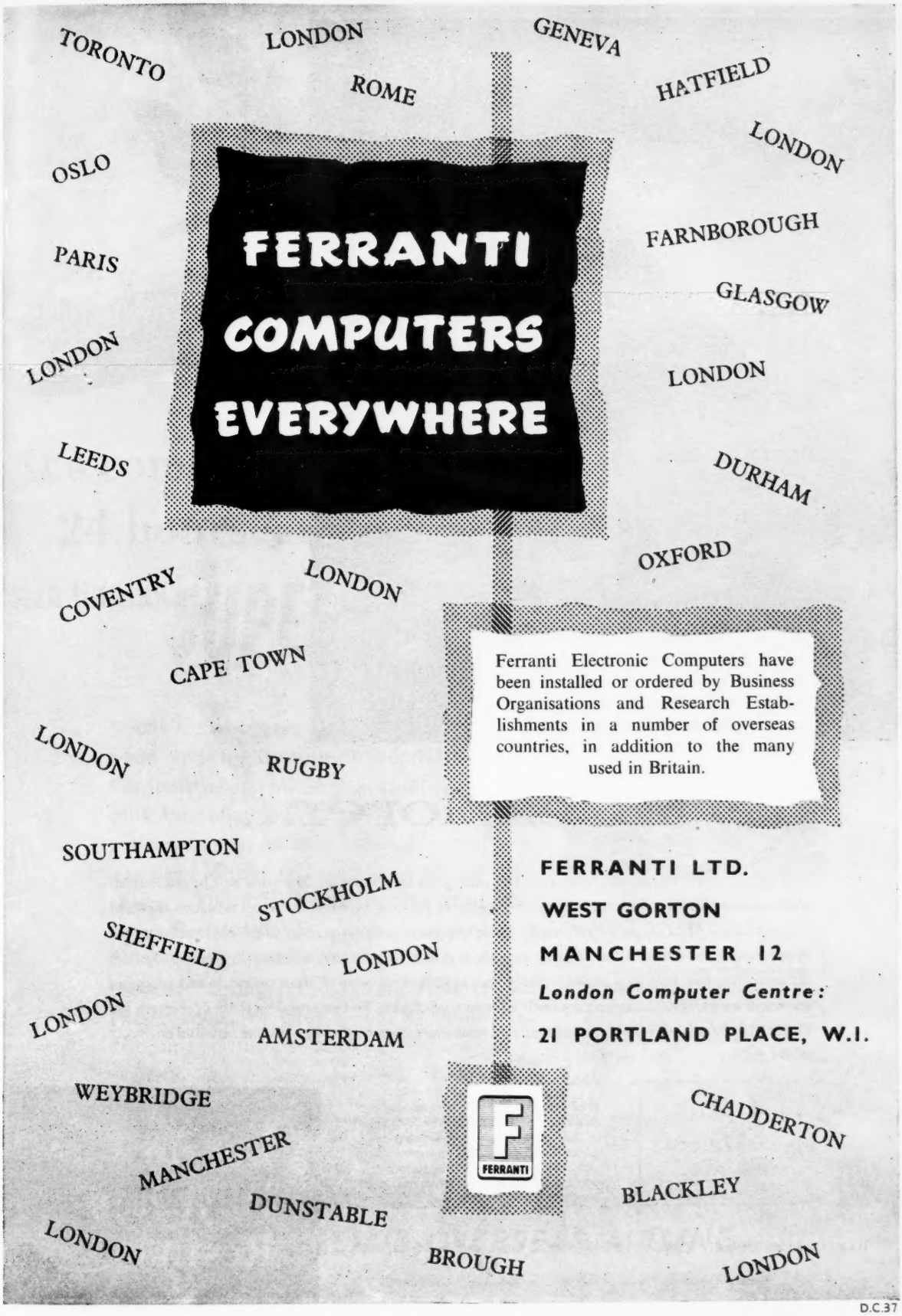
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aerial explorer...

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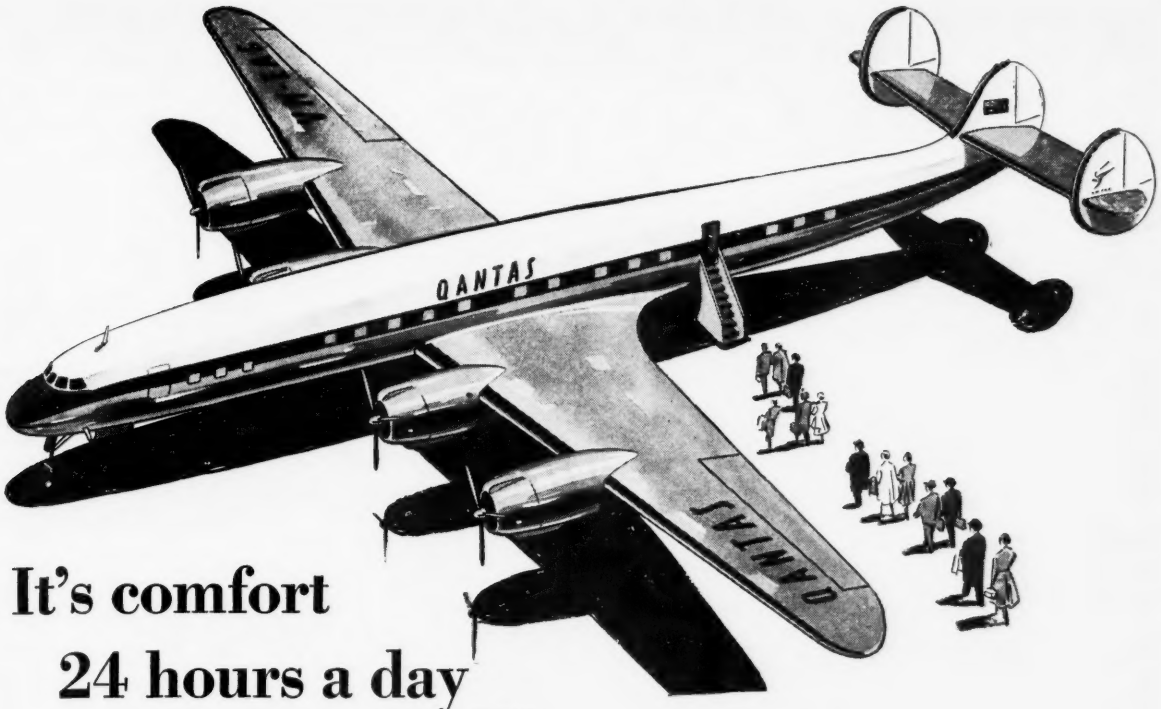

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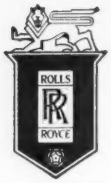

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Journal of

THE ROYAL AERONAUTICAL SOCIETY

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All communications for publication in, and advertisements for, the JOURNAL *should be addressed to the Editor,* JOAN BRADBROOKE, *A.R.Ae.S.; all communications on general matters affecting the Society should be addressed to the Secretary,* A. M. BALLANTYNE, *T.D., B.Sc., Ph.D., Hon.F.C.A.I., A.F.I.A.S., F.R.Ae.S.*

None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless otherwise stated.

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The Royal Aeronautical Society

(Founded 1866)

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Secretary's News Letter

December 1956.

ALL MEMBERS of the Society at Home should have received by now a NOTICE concerning the Address by the President, Mr. E. T. Jones, and an APPLICATION FORM for tickets for the Reception which will follow the Address.

The venue has been changed—it will be held at CHURCH HOUSE, Westminster, on 10th January 1957 in the Hall in which H.R.H. The Duke of Edinburgh gave the Commonwealth Lecture in December 1954, and will commence at 6.30 p.m.

Perhaps some will wish to attend the Address, but find it impossible to attend the Reception afterwards. This will be possible.

The Assembly Hall in Church House can accommodate more than 700; since Ladies will be welcomed at both the Address and the Reception it only means 350 couples and the Hall will be almost full. I hope that the attendance will reach a record figure—the membership of the Society is increasing and the attendance should increase also.

I have the attendance records for lectures during the past twelve months, and I must confess they make sorry reading. Why this should be so, I do not know. The lectures start too early (or too late)? The publicity is not good? Yet — attendances at All-Day Discussions have now to be limited to ticket holders, both members and non-members. A lecture by a Yeager fills the Hall. This year we have distributed more posters than ever before, so perhaps members themselves have to overcome no little inertia.

Whatever the reason for the small attendances in the past, I hope that 1957 will show a definite increase in the activities of the Society, beginning with the Presidential Address and continuing through the Sixth Anglo-American Aeronautical Conference. I well remember the 50th Anniversary Dinner held on 17th December 1953. The enthusiasm for that was such that there was a waiting list for tickets, which were taken up eagerly as they became available.

The Sixth Anglo-American Conference will be held at Folkestone during the second week in September 1957. Details are, at present, being worked out and they will be given as soon as possible. The Garden Party will be held on Sunday 15th September 1957; this is the tentative date, for it is hoped to let our American friends enjoy an occasion which, we think, is enjoyable.

As you read this you will be thinking of Christmas, so perhaps I should conclude by wishing all members of the Society

A Merry Christmas

from the Staff of the Society
and

A. M. Ballantyne

Secretary

NOTICES

An annual sum of £250 is available for premium awards for papers, including Technical Notes, published in the Journal. Members and non-members of the Society are invited to submit papers on any aspect of aeronautics

Christmas 1956

The President, Mr. E. T. Jones, the Council and Staff of the Society wish all members at home and overseas a very happy and peaceful Christmas.

The Library and Offices of the Society will be closed for the Christmas Holiday from 5 p.m. on Friday 21st December to 9 a.m. on Thursday 27th December 1956.

The Fairey Delta Lecture

It is regretted that the lecture by Mr. R. L. Lickley, F.R.Ae.S., and Mr. Peter Twiss on "The Fairey Delta" which was to have been given on 4th December, has had to be postponed.

It will now be given on *Thursday 14th February* 1957, at 6 p.m. at the Institution of Mechanical Engineers.

The N. E. Rowe Medals Competition

A new type of lecture is to be instituted on Tuesday 15th January 1957, when two short papers will be read to decide the winner of one of the N. E. Rowe Medals for 1956-57.

The competition, which was initiated this year, is for the best paper on a technical topic by a young member from one of the Branches. There are two medals to be awarded, provided that the entries be of sufficient merit, one for under-21s, and the other for the under-26s. The entries are judged by the Branches Committee of the Society, but if there be no paper clearly the best, the rules provide for the Competitors being subjected to the further test of reading them before the Graduates' and Students' Section in London, and answering questions on their papers from the audience.

This year, there are two papers in the over-21 class of great merit: "Possible Flight Paths for Helicopters" by Mr. P. F. Sutherby of the Bristol Branch, and "Fins" by Mr. J. Wolkovitch (*Student*) of the Southampton Branch.

It is hoped that a large audience will be present to encourage the speakers and to test them with their questions. The first lecture will start at 7.30 p.m. in the Library, 4 Hamilton Place, being preceded by tea at 7 p.m.—N.K.B

New Prices for Journal Binding

We regret that because of increased costs in the printing and publishing trade during this past year, prices for the permanent binding of Journals have had to be increased for 1957. The new charges will be:—

Permanent Binding

1956 Volume (including packing and postage) £1 2s. 6d.

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Journals, with a note of the name and address of the sender, should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the Offices of the Society.

Members are asked to be certain that the address to which they want their Journals sent is the same on their letters to the Lewes Press and to the Society.

Self-Binder Cases

Self-Binder cases of the "Easibind" type to hold 12 Journals (cost 11s. 6d. each) are available from the offices of the Society.

Presidential Address

The President, Mr. E. T. Jones, C.B., O.B.E., F.R.Ae.S., will give his Presidential Address on Thursday 10th January 1957 at 6.30 p.m. at Church House, Westminster, S.W.1. Tea will not be served before the address.

The Chair will be taken by Lord Brabazon of Tara, M.C., P.C., Hon.F.R.Ae.S.

Following the Presidential Address a Reception will be held at Church House from 7.30-10.00 p.m. A buffet supper will be served and at intervals during the evening there will be a Film Show. Tickets for the reception will be £1 1s. 0d. each, inclusive of supper. Dress will be dinner jacket or dark lounge suit.

Home members have already been sent an application form for the Reception but if any member has not received one he should apply to the Secretary.

Members do not need tickets for the Presidential Address and it is hoped that even if they are unable to come to the Reception they will attend the Address.

Southern Africa Division

The Hon. Secretary of the Southern Africa Division is now Mrs. D. D. Hughes, *Companion*. Her address is c/o Southern Africa Office, Bristol Aeroplane Co. Ltd., 53/54 Norwich Union Building, 91 Commissioner Street, Johannesburg. Mrs. Hughes was elected a Companion of the Society in April this year.

"Transonic Wind Tunnel Testing Techniques"—All-Day Section Lecture and Discussion, Thursday 20th December 1956

Admission by Special Ticket Only

On Thursday 20th December 1956 the Society is holding an all-day meeting at the Institution of Mechanical Engineers, starting at 10.00 hours. The Chairman will be Major G. P. Bulman, and five introductory papers will be read by Mr. H. F. Vessey, Mr. R. Hills, Mr. J. A. Kirk, Mr. F. O'Hara and Mr. F. E. Roe. This meeting promises to be of considerable interest to those involved in any way with the use of Wind Tunnels or the data provided by them.

To avoid disappointment and to ensure the admission of members wishing to attend, it has been decided that on 20th December *admission will be by special ticket only* for members and non-members alike.

Members: Tickets will be issued upon request to the Secretary to members of the Society *by name only* until Thursday 13th December, when any seats not taken will be made available to non-members.

Non-Members: No visitors' tickets will be issued before 13th December, one week before the lecture, when any seats not required by members will be made available to non-members. Requests should be sent to the Secretary as soon as possible as they will be dealt with in strict rotation.

The Secretary regrets that it is necessary to impose these restrictions but hopes that this arrangement will avoid inconvenience to members.

DIARY

LONDON

11th December

SECTION LECTURE.—Materials for Aircraft Structures Subjected to Kinetic Heating. Professor A. J. Murphy. Library, 4 Hamilton Place, London W.1. 7 p.m.

17th December

Main Lecture at Reading Branch.—Transferred to 26th MARCH. Current and Future Development in Civil Aviation. Peter G. Masefield.

20th December

ALL DAY SECTION LECTURE ON TRANSONIC WIND TUNNEL TESTING TECHNIQUES.—Introductory papers will be read by: H. F. Vessey, R. Hills, J. A. Kirk, F. O'Hara, F. E. Roe. The Institution of Mechanical Engineers, Birdcage Walk, London S.W.1. 10 a.m. *Admission will be by ticket only.* See Special Notice.

3rd January 1957

YOUNG PEOPLE'S LECTURE.—Experiences of an Airline Pilot. Capt. O. P. Jones, C.V.O., O.B.E. The Royal Society of Arts, 6 John Adam Street, London W.C.2. 3 p.m.

8th January

SECTION LECTURE.—The Significance of Flow Separation in Three Dimensions. E. C. Maskell. Library, 4 Hamilton Place, London W.1. 7 p.m.

10th January

PRESIDENTIAL ADDRESS.—E. T. Jones, C.B., O.B.E. The Institution of Mechanical Engineers. Birdcage Walk, S.W.1. 6 p.m. *See* special notice.

17th January

SECTION LECTURE.—Electronic Control Techniques in Aircraft Manufacture. G. S. Kermack and H. Ogden. Library, 4 Hamilton Place, London W.1. 7 p.m.

24th January

MAIN LECTURE.—Aeronautical Research in Holland. Prof. Dr. Ir. H. J. van der Maas. The Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea 5.30 p.m.)

29th January

SECTION LECTURE.—Design for Production. E. D. Keen. Library, 4 Hamilton Place, London, W.1. 7 p.m.

GRADUATES' AND STUDENTS' SECTION

15th January

N. E. ROWE MEDAL COMPETITION.—Possible Flight Paths for Helicopters, P. F. Sutherby. Fins, J. Wolkovitch. Library, 4 Hamilton Place, London W.1. 7.30 p.m. *See* special notices.

BRANCHES

10th December

Henlow.—Student Members' Lectures. Building 62, R.A.F. Technical College, Henlow. 7.30 p.m.

12th December

Christchurch.—American Production Methods. J. A. Mackenzie. Ball Room, King's Arms, Christchurch. 7.30 p.m.

Coventry.—Lectures by Junior Members. The Wine Lodge, The Burges, Coventry. 7.30 p.m.

Leicester.—Annual General Meeting and Film Show. Lecture Theatre, Loughborough College. 6.30 p.m.

Manchester.—The Structural Effects of Kinetic Heating in Supersonic Flight. Dr. P. B Walker. C.B.E. Reynolds Hall, College of Technology, Manchester. 7.30 p.m.

Merthyr Tydfil.—Films arranged by K. P. Bryant. Teddington Aircraft Controls, Cefn Coed.

Preston.—Novel Methods of Take-Off and Landing. T. J. Cummings. Queen's Hotel, Lytham. 7.30 p.m.

Southampton.—Fourth Mitchell Memorial Lecture. Noise and Aircraft Structures. Professor E. J. Richards. Lecture Theatre, Institute of Education, University of Southampton. 7 p.m.

13th December

Bristol.—Film Show. Conference Room, Filton House, Bristol Aircraft Ltd. 6 p.m.

Brough.—Flying Saucers. Desmond Leslie. Lecture Hall, Yorkshire Electricity Board, Ferensway, Hull. 7.30 p.m.

13th December

Cheltenham.—Accident Investigation. Lt. Cdr. F. R. Fenton. St. Mary's College Cheltenham. 7.30 p.m.

Isle of Wight.—Annual General Meeting and Film Show. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, E. Cowes. 6.30 p.m.

14th December

Weybridge.—Annual Dance.

19th December

London Airport.—Films: London Airport Approach; Emergency Evacuation of Aircraft. Viking Centre, Halton Cross. 6 p.m.

20th December

Belfast.—Debate: There are too many Aircraft Companies in the British Isles. Kensington Hotel, Belfast. 7 p.m.

4th January 1957

Preston.—Annual Dance. Imperial Hotel, Blackpool.

7th January

Derby.—The Boeing 707. K. Luplow. Rolls-Royce Welfare Hall, Nightingale Rd., Derby. 6.15 p.m.

Glasgow.—History of the Britannia and its Development. A. Symon. Royal Technical College, Glasgow. 7.15 p.m.

8th January

Belfast.—Aircraft Inspection. I. R. Smith. Kensington Hotel, Belfast. 7 p.m.

Boscombe Down.—Defence Policy. Marshal of the R.A.F. Sir John Slessor, G.C.B., D.S.O., M.C. Lecture Hall, A. and A.E.E., Boscombe Down, Amesbury. 5.45 p.m.

9th January

Chester.—Artificial Satellites and Space Travel. C. A. Cross. Grosvenor Hotel, Chester. 7.30 p.m.

Gloucester.—Design of the S.K.1. Light Aircraft. H. Kendall, M.B.E. The Wheatstone Hall, Brunswick Road, Gloucester. 7.30 p.m.

Luton.—A Debate: That this House Considers that the Designer is Hamstrung by Production Methods. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

Weybridge.—Brains Trust: Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd., Weybridge. 6 p.m.

10th January

Bristol.—Design Problems of Modern Wind Tunnels. R. Hills. Conference Room, Filton House, Bristol Aircraft Ltd. 6 p.m.

Isle of Wight.—Two Thousand Years of Aerodynamic Research. J. L. Pritchard, Hon. Fellow. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, E. Cowes. 6.30 p.m.

Merthyr Tydfil.—Elements of the Aero Gas Turbine. S. L. Bragg. Teddington Aircraft Controls, Cefn Coed.

14th January

Henlow.—Aircraft Control. Prof. G. A. Whitfield. Bldg. No. 62, R.A.F. Technical College, Henlow. 7.30 p.m.

Southampton.—Annual General Meeting and Film Show. Lecture Theatre, Loughborough College, Leicester. 6.30 p.m.

16th January

Christchurch.—Problems and Prospects in Civil Air Transport. P. G. Masefield. Town Hall, Christchurch. 7.30 p.m.

Leicester.—Agricultural Aviation. J. E. Harper, A.F.C. Lecture Theatre, Loughborough College, Leicester. 6.30 p.m.

17th January

Bristol.—Wind Tunnel Instrumentation. J. R. Anderson. Conference Room, Filton House, Bristol. 6 p.m.

18th January

Birmingham.—Aerial Survey. Mr. Dawe. Birmingham Engineering Centre, Stephenson Place, Birmingham. 7.15 p.m.

20th January

Brough.—Gliding. J. C. Neilan. Lecture Hall, Yorkshire Electricity Board, Ferensway, Hull. 7.30 p.m.

24th January

Bristol.—The Application of Wind Tunnel Results to Aircraft Design. M. Wilde. Conference Room, Filton House, Bristol Aircraft Ltd. 6 p.m.

Diary continued

30th January

Preston.—Diving and Underwater Engineering. I. Fraser, V.C., D.S.O. R.A.F. Association, Preston. 7.30 p.m.

Southampton.—Atomic Energy for Aircraft Propulsion. J. E. Perkins. (Joint Meeting with the Institute of Production Engineers (Southern Section).) Lecture Theatre, Institute of Education, University of Southampton. 7 p.m.

Weybridge.—Electronics and the Aircraft Industry. Dr. C. F. Bareford. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6 p.m.

News of Members

S. Ajaz Ali (*Associate*), formerly Senior Inspector of Aircraft in the A.I.D. Civil Aviation Department, Government of Pakistan, is now Chief Inspector Engineering Division of Pakistan International Airline Corporation.

Flying Officer J. A. F. Allan (*Graduate*), formerly Aircraft Production and Storage Officer and M.T.O. at No. 45 M.U., is now with the Technical Wing of the Royal Air Force at Coltishall.

A. W. Bedford (*Associate*) has been appointed Chief Test Pilot of Hawker Aircraft Ltd. He was formerly Assistant Chief Test Pilot with the Company.

R. A. Berridge (*Associate Fellow*), formerly Works Manager at Hale, Hamilton and Co., Uxbridge, is now Sales Engineer with Aero Research Ltd., Duxford.

F. Bradford (*Associate Fellow*) is now Principal Designer (Prototype Aircraft Development) with the English Electric Company at Warton Aerodrome, Lancs.

J. T. Burr (*Associate Fellow*) has been appointed Senior Systems Engineer at the London Design Office of Bristol Aircraft Ltd.

D. Cardwell (*Associate Fellow*) is now Assistant Director (Basic Research) Fighting Vehicles Research and Development Establishment, Chertsey.

Squadron Leader C. H. W. Champness (*Associate*) has been posted from Air Engineer 1 in the Air Ministry to R.A.F. Khormuksar as O.C. Engineering Squadron.

M. G. Cherry (*Graduate*), formerly with Armstrong Siddeley Motors, is now with Orenda Engines Ltd. in Toronto as an Aerodynamic Engineer (B) working on compressor design.

A. R. Dare (*Graduate*), formerly with Canadair Ltd., is now with Northrop Aircraft, Hawthorne, California.

E. J. Davis (*Associate Fellow*) is now a co-ordinator of Design (N113) at Vickers-Armstrongs, Supermarine Works.

Wing Commander N. G. N. Davis (*Associate Fellow*) has retired from the Royal Air Force and is now a Service Engineer with A. V. Roe and Co. Ltd.

K. H. Dickenson (*Associate Fellow*), formerly with Handley Page Ltd., is now in the Stress Office of Avro Aircraft Ltd., Toronto.

Squadron Leader N. F. Duke (*Associate*) has resigned from his position as Chief Test Pilot of Hawker Aircraft Ltd.

R. A. Fry (*Associate*) has left the Air Registration Board and has been appointed to the Staff of the International Civil Aviation Organisation and will be joining the Technical Mission to Indonesia.

W. J. Gornall (*Associate Fellow*) has taken up an appointment as Engineer (Grade 3 acting) Project Stress Engineer at the Government Aircraft Factories, Melbourne.

T. G. Guppy (*Associate Fellow*), formerly with de Havilland Aircraft Ltd., is now the Senior Design Engineer, Weapon Research Division of A. V. Roe and Co. Ltd. at Harrow.

G. W. Hall (*Associate Fellow*) is now Vice-Chairman of the Fairey Aviation Co. Ltd. This is additional to his appointment as Managing Director.

Wing Commander R. F. Harman (*Associate*) has been appointed Senior Instructor at the R.A.F. Flying College, Manby, Louth, Lincs.

N. Herbert (*Associate Fellow*) has been appointed Lecturer in Production Engineering at the College of Technology, Chesterfield.

E. W. Humphreys (*Associate*) has left the Fairey Aviation Co. Ltd. to take up an appointment with S. J. Noel-Brown and Co. Ltd., Management Consultants.

Air Marshal Sir Owen Jones (*Fellow*) has retired from his position of Controller of Engineering and Equipment at the Air Ministry.

M. Langley (*Fellow*) has resigned from his position as Managing Director of Tiltman Langley Ltd. He will remain a Director.

R. L. Lickley (*Fellow*) is now Technical Director of the Fairey Aviation Co. Ltd. He is retaining his appointment as Chief Engineer.

S. D. Meston (*Associate Fellow*), formerly at Fairey Aviation Co., has now taken up an appointment as a Mechanical Engineer with the Sperry Gyroscope Co. Ltd. at Brentford.

H. A. Money (*Student*) has taken up an appointment as a Technician at Saunders-Roe Ltd., E. Cowes.

Flight Lieut. J. J. C. Oakley (retd.) (*Associate Fellow*), formerly of Vickers-Armstrongs (Supermarine) Ltd., has joined the Structural Test Department of Folland Aircraft Ltd.

D. G. Oliver (*Associate Fellow*) is now Section Leader in the Drawing Office of Bristol Aircraft Ltd. at their Bournemouth Design Office.

J. Lankester Parker (*Fellow*) was installed as Master of the Guild of Air Pilots and Air Navigators at Innholders Hall on 17th October.

G. R. Peel (*Associate*), formerly Training Officer of Stewarts and Lloyds Ltd., is now Training Officer with the Igranic Electric Co. Ltd.

Air Commodore M. E. M. Perkins (*Associate Fellow*), formerly at Headquarters Fighter Command as Senior Technical Staff Officer, has been appointed to command the R.A.F. Station, St. Athan, Glamorgan.

Wing Commander A. H. Porter (*Associate*), formerly at R.A.F. Changi, Singapore, is now Senior Technical Officer, R.A.F. Odiham.

G. G. Roberts (*Associate Fellow*) has been appointed Director of Research with Smiths Aircraft Instruments Ltd. He was formerly Technical Executive of Guided Weapons with the Company.

C. T. Sculthorpe (*Associate Fellow*) is now Section Leader, Engine Installation and Fuel Systems, Design Department, Sir W. G. Armstrong Whitworth Aircraft Ltd.

H. G. Sevier (*Associate Fellow*) has now taken up a post in the Engineering Department of Bristol Aircraft (Western) Ltd. at Winnipeg, Canada.

W. B. J. Shakespeare (*Associate Fellow*), formerly of Canadair, Montreal, is now employed at Northrop Aircraft Inc., Hawthorne, California, as Engineering Designer.

Air Commodore T. U. C. Shirley (*Associate Fellow*) on completing the 1956 Course at the Imperial Defence College has been appointed Air Officer Commanding and Commandant of the R.A.F. Technical College, Henlow.

G. Sim (*Associate Fellow*) has resigned from his post as Head of the Wind Tunnel Department at Vickers-Armstrongs (Aircraft) Ltd., and has taken up an appointment with Lockheed Aircraft Corporation, California Division, Burbank, California.

A. Taylor Smith (*Graduate*), formerly with Vickers-Armstrongs (Supermarine) Ltd. at Hursley Park, is now working in the Special Projects Division of Avro Aircraft Ltd., Malton.

A. Syme (*Graduate*), formerly Technical Assistant with D. Napier and Son, Luton, is now with Rolls-Royce Ltd., Derby, as a Quality Engineer.

J. C. C. Taylor (*Associate*), formerly Aviation Sales Manager with Shell-Mex and B.P. Ltd., has been appointed Aviation Consultant to the British Petroleum Co. Ltd.

B. R. TEREE (*Associate Fellow*), formerly with the Weatherhead Co. of Cleveland, Ohio, has been appointed Chief Engineer of Greer Hydraulics Inc., Jamaica, New York.

W. THORNHILL (*Associate Fellow*) has joined Westland Aircraft Ltd. as Assistant to the Sales Manager.

A. H. TILTMAN (*Fellow*), formerly Chairman and Technical Director of Tiltman Langley Ltd., is now President of the Company.

A. VINES (*Associate Fellow*) is now Production Director of the Fairey Aviation Co. Ltd. He was formerly Production Manager of the Company.

Flight Lieut. R. WALTER (*Associate Fellow*) has retired from the Royal Air Force and is now at the Air Ministry.

G. A. WEAREN (*Associate*), formerly Chief Service Engineer of the de Havilland Aircraft Co. Ltd., is now Assistant to the General Service Manager of Bristol Aircraft Ltd.

Air Commodore Sir FRANK WHITTLE (*Hon. Fellow*) was awarded the Franklin Medal, the highest honour of the Franklin Institute, at Philadelphia on 17th October, for his "pioneer work in developing aircraft engines and high-speed flight."

Group Captain D. W. WILLIAMS (*Associate Fellow*) has ceased to command No. 12 R.A.F. School of Technical Training and has taken up the appointment of Command Engineer Officer, Headquarters 2nd Tactical Air Force.

B. C. WHORWOOD (*Student*), formerly Design Draughtsman with Handley Page Ltd., is now commissioned in the Royal Air Force with the G.D. (Navigator) Branch in the substantive rank of Pilot Officer.

Dr. H. M. WILSON (*Associate Fellow*) has been promoted to Chief Scientific Officer and appointed Deputy Director General of Aircraft Equipment Research and Development at the Ministry of Supply.

L. A. WINGFIELD (*Associate*) was presented with an inscribed silver salver by the Guild of Air Pilots and Air Navigators on 17th October in appreciation of his 27 years' service as Clerk of the Guild. He has also been appointed Chairman of Tiltman Langley Ltd.

AMELIA EARHART SCHOLARSHIP

The annual Amelia Earhart Scholarship to encourage graduate study by women in the field of aeronautical engineering, is offered by Zonta International for the year 1956-57. Twenty awards have been made since the scholarship was established in 1938 to honour Amelia Earhart, who was a member of Zonta International at the time of her disappearance in 1937. The terms of the grant are:—

1. Scholarships of $1,800 each will be awarded annually to one or more women for graduate study in engineering with special interest in aeronautics.
2. The scholarships may be used in any approved schools where aeronautical work of a high order is offered on the graduate level.
3. A grant of the scholarship may be renewed for a second year, if the holder of the scholarship is better qualified to go on with study than any new applicant.
4. A Committee made up of members of Zonta International will pass on the applications and make the award. The decision of this Committee shall be final, except for ratification by the Board of Zonta International.

For further information and application forms, write to Zonta International, Dr. Helen Pearce, Chairman, 490 Oak Street, Salem, Oregon, U.S.A. Applications must be in by 1st March 1957.

ELECTIONS

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

Dennis Abraham
Yelagalawadi Vedavyasa Gururaj Acharya
Derek Marson Anthony
Paul John Bellerby (*from Graduate*)
Derek George Brown (*from Graduate*)
Herbert Frank Butler
Norman Stanley Currey (*from Graduate*)
Brian Ronald Diplock (*from Graduate*)
Robert Welsford Durrant (*from Associate*)
Douglas Howard Fears (*from Student*)
Ralph Foster
Stewart Douglas Hall (*from Associate*)
Harry John Hartland
Hugh Geoffrey Herrington
John Dennis Hodge (*from Graduate*)
Peter Lionel Hughes (*from Graduate*)
Arthur Francis Hutton
Donald Albert Jobson (*from Graduate*)
John Burgoyne Joyce
John Denis Mann (*from Graduate*)
Dorian Farrar Mowbray
Sidney Harry Parker
Denis John Powell (*from Graduate*)
Reginald William George Ranner (*from Associate*)
Wladimir Alexander Reichel
Ronald Leon Samuels (*from Graduate*)
Alfred Sewart
Barry Dudley Smith
Brian Stapleton Stratford
William Trevarton Truscott
Reginald Utting (*from Graduate*)
Gordon Josiah Wedgwood (*from Graduate*)

Associates

Raymond Reynolds Atwood
Edward William Cornford
James Joseph Farrell
Reginald Godfrey Feltham
Albert Edward Geddes
Alfred Norman Haskett
John Robert Holmes
Tom Foster Kennedy
John Stanley Lee
Theodore Jasper MacLean de Lange
Stanley George Partridge
Howard Reginald Smith
Ernest Donald Sutton
John Allan Swetman
James McGough Taylor
John Alexander Terras
Alan Bruce Thompson
Wallace Lionel Underwood
Desmond Ronald Wyett

Graduates

Donald Vincent Baker (*from Student*)
Peter Newall Cockshott
Maurice John Cooper
Michael Victor Ley Cooper
Paul Rogerson Gleave (*from Student*)
John Louis McLean
John Harold Marsh
John Christopher Middleton
John Alan Porter (*from Student*)
Clive Noel Roberts
Wilfred Edwin Sharpe
Michael Kevin Shaw
Arthur Brian Taylor (*from Student*)
David Bruce Turner (*from Student*)
Dennis Walker
James Oswald Yost

Students

William James Frederick Brown
John Laurie Buckworth
Shailendra Kumar Chakraborty
David Ernest Chamberlain
Robert Newton Compton
Brian Dingle Coombe
Terence Godfrey Dale
Martin Davis
Donald Reginald Gray
Madan Lal Jaggi
John Leslie Charles Littlefield
Robert Ashley Marshall
Michael Martin
Trevor William Miles
Christopher George Buxton Mitchell
Gordon Hugh Fitzmaurice Nayler
Edward Thomas Paddison
John Simon Rogger
Jeffrey Brian Rose
Derek Rouse
Nishithendu Lal Roy
David Brian Sherriff
Kenneth Frederick Topp
Barry John Lister Watts
James Frank Weatherhead
Brian Alfred Nelson Wimshurst

Companions

Heinrich Rudiger Ilgen
Samuel George Robbins (*from Graduate*)
Bernard Roy West

The Derry and Richards Memorial Medal

The Derry and Richards Memorial Medal, awarded each year by the Guild of Air Pilots and Air Navigators for experimental flying, is to be presented for the year 1955, to Mr. Peter Twiss, of Fairey Aviation Ltd., for his work on high speed delta aircraft leading up to the World Air Speed Record runs.

A "Classical" Quotation

The American Journal "U.S. Air Services" shows each month on its cover a "classical" quotation connected with aeronautics. A tribute is paid on the front of the November issue to the late A. G. Lamplugh (*Fellow*) with his "Aviation in itself is not inherently dangerous, but to an even greater extent than the sea it is terribly unforgiving of any carelessness, in capacity, or neglect." This is a paraphrase of the peroration to his paper "Accidents in Civil Aviation" which was delivered before the Society in 1931.

Changes of Address or Appointment

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address. He would also like to know of any change of appointment.

When notifying changes please give the following particulars:—

New address (in block letters). Grade of Membership.
Name (in block letters). Old address.

New appointment.—Please give name and address of employer and position held.

Change of address must be received *before the 15th of the month* in order to be effective for the Journal for the following month.

Annual Subscriptions

Members are reminded that their annual subscriptions become due on 1st January 1957. The rates are:—

	Home	Abroad
	£ s. d.	£ s. d.
Fellows	5 5 0	4 4 0
Associate Fellows	4 4 0	3 3 0
*Associates	3 3 0	3 3 0
Graduates (aged under 26)	2 2 0	2 2 0
Graduates (aged 26 and over)	2 12 6	2 12 6
Students (aged under 21)	1 1 0	1 1 0
Students (aged 21 and over)	1 11 6	1 11 6
Companions	3 3 0	3 3 0
Founder Members	2 2 0	2 2 0

* Any Associate elected before 1st October 1947 may, if he wishes, elect not to receive the Journal, and in this case his subscription will be reduced by £1 1s. 0d. to £2 2s. 0d.

It will avoid delay and confusion if members, when sending remittances for subscriptions, will state their names clearly and give their addresses and grades of membership. Remittances should be made payable to the Royal Aeronautical Society.

The Journal of the Royal Aeronautical Society
WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

VOLUME 60 DECEMBER 1956 NUMBER 552

SIR RICHARD FAIREY, M.B.E., Hon.F.I.A.S.

Honorary Fellow

5th MAY 1887 - 30th SEPTEMBER 1956

(*President of the Royal Aeronautical Society* 1931-1934)

MAN IS GREATER than his achievements, though the latter often have greater historical impacts.

Charles Richard Fairey was a man greater than his achievements, great though they were. He will be remembered by all who knew him, by those who were associated closely with him in work or in play, as "a proper man, as one shall see in a summer's day."

In February 1938 he gave a broadcast account of his early days.

"I had a somewhat pampered childhood as the only son of a large Victorian family, and believe me, that is a very soft job. My father was a City merchant in comfortable circumstances and in due course I went to a public school. Then came a shock. On my father's death the family discovered that they were virtually penniless."

At the age of 15 he started working with the Jandus Electric Company in Holloway, in 1902, at a wage of 5s. a week. The managing director of the Company was alive to the potentialities and characters of those who came to work for the firm. The youthful Fairey was given the privileges of a premium apprentice, so that he obtained that early practical training which the successful engineer must have. For theory he paid out a few of his hard earned shillings each term to the Finsbury Technical College, where one of his teachers was the famous Sylvanus Thompson.

For five nights a week he studied hard.

"On leaving the factory," he said in his broadcast, "I had an hour in which to get home, have tea, and go down to Finsbury—that was four miles from the factory and penny tram fares counted. They were cable trams in those days up the City Road—much faster than a horse bus. I saw my first motor bus during one of these journeys. Nevertheless, in due course I managed to pass my final examination as an electrical engineer."

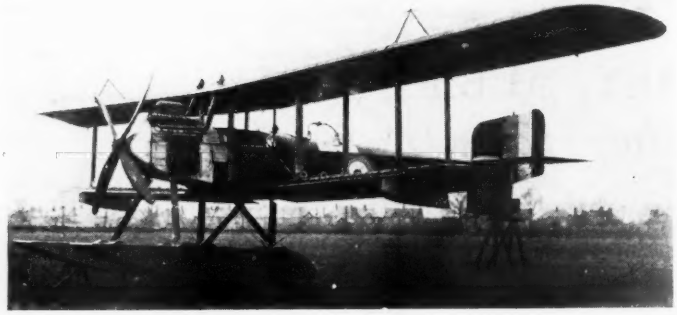
For his firm, at the age of 18, he carried out a job at Heysham Harbour with considerable success, and over thirty years later commented, "I then got a swollen head and a few months afterwards the sack."

There is nothing more stimulating to a man of the right temperament than to get a swollen head followed by the sack. Richard Fairey had taken four subjects in his courses at Finsbury Technical College, and one of them enabled him to become an analytical chemist with the Finchley Urban District Council. As a side line, so he could become wholly self-supporting, he added to his earnings by teaching engineering subjects at Tottenham Polytechnic and the Finchley Technical College.

Sir Richard Fairey. From the portrait by Cuthbert Orde, painted for the Society.

At an impressionable age he had learnt the great lesson that increased wages come from increased output.

Those were the days when the gramophone and the telephone were somewhat primitive, strange and exciting; when most shorthand typists were men; when gas mantles were more common in private houses, on railway stations, and in street lamps, than electric bulbs; when cigarettes were 5½d. for 20; when a cut off the joint and two veg., followed by a substantial suet pudding and a cup of coffee cost 1s. or less; when the motor car followed the red flag and Edward VII was on the throne.



The Fairey Campania (Rolls-Royce Eagle) 1916.

In 1903 the Wright Brothers flew in America; in 1906 Santos Dumont made the first aeroplane flight in Europe; and in the same year the young A. V. Roe was to win a model aeroplane competition at Alexandra Palace. Four years later, at a meeting of the Kite and Model Aeroplane Association, C. R. Fairey won the first prize for a monoplane model, which flew 460 feet. One of the judges of the competition was Major Baden-Powell who had been President of the Aeronautical Society from 1901 to 1907.

The Fairey Monoplane (prophetic entry in the list of competitors!) was good enough for an enterprising London store to pay a generous sum of money for the right to reproduce it. Fairey soon found himself constructing a full-size monoplane, with a 20 h.p. Advance engine, on behalf of Everitt and Edgecumbe at Hendon. The open fields on which he carried out his taxying trials and short hops became the Hendon Aerodrome.

His model had, inadvertently, infringed an early patent of J. W. Dunne, who had developed a highly stable tailless aeroplane with swept-back wings. This infringement led to a meeting with Dunne, and in 1911 Fairey took up a position as manager to the Blair Atholl Syndicate which was building Dunne machines at Eastchurch in the Isle of Sheppey. Fairey was very much concerned with making four of Dunne's aeroplanes while there, a first class apprenticeship for the future.

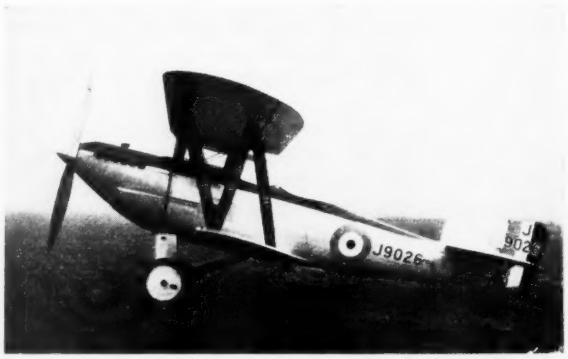
"Then followed the most blissful period of my life," he declared, speaking of his Eastchurch days. "Here I was at last in the middle of things, getting flying experience with whoever would provide it, studying the structural and other problems in connection with the Dunne aeroplane and enjoying myself very much indeed. They were amazing machines we flew in those days: queer frail apparatus with wing loadings as low as 2 lb. to the square foot and weighing sometimes 30 lb. to the horsepower; far more thrilling and enjoyable to fly than modern aeroplanes."

Eastchurch was the very cradle of British aviation. At that time Alec Ogilvie had a shed next to one used by J. W. Dunne. There, also, was Harris Booth, who had been working for a time at the National Physical Laboratory. Later, at the Admiralty (with Harold Bolas) he prepared the famous memorandum on a modification of the Three Moments equation for a beam with end loads, which led to the well-known Berry functions. There, too, was Francis McClean, T. P. Searight, Vincent Nicholl, F. G. T. Dawson, Maurice Wright, Gordon Bell, Horace and Oswald Short and many others who did so much to give British aviation such a wonderful start. Dawson, Nicholl and Wright were all, later, to help Richard Fairey to found and build his Company. No wonder Fairey called it "the most blissful period of my life," for he was working side by side with those who gave their hearts and energies to the greatest adventure in the world's history, the conquest of the air, as he gave his own heart and skill and energy for the rest of his life.

In 1913 Fairey joined Short Brothers to work with that brilliant aviation genius Horace Short. When the firm opened their new factory at Rochester, Fairey left the Isle of happy memories.

He had early visualised having his own organisation, being able to build his own machines; but neither the naval nor the army mind was to be easily convinced, even when, in the summer of 1914, it became clear the

The Fairey III F 1926. One of the famous series III which was built in many versions.



The Fairey Fox 1925. Two-seat day bomber which had a maximum speed of 156 m.p.h.

The Fairey Aviation Co. Ltd. Works, Hayes, 1918.

war was very close, that any more aircraft companies were wanted. When the war did break out, Fairey, like Maurice Wright and Vincent Nicholl, tried to join the Royal Naval Air Service, but was told by Sir Oliver Swann to stay where he was, and not argue, "as there were less than six aircraft designers in the country!"

In 1915 he registered the Fairey Aviation Company and was backed in his adventure by Dawson and Nicholl and Maurice Wright. Dawson was invalided out from the Dardanelles towards the end of 1915 and was able to join the Company and give it great help with its early finances. Following the end of the war both Nicholl and Wright were able to add their experience and knowledge.

Short Brothers gave their late chief engineer a splendid start by giving the Company its first real job, to build a dozen Short seaplanes, which were flown in the first instance by Sidney Pickles, who thus became the firm's first test pilot. For launching and testing these machines, Admiralty sheds were obtained on the Hamble River, so forming the beginning of the Hamble works of the Company.

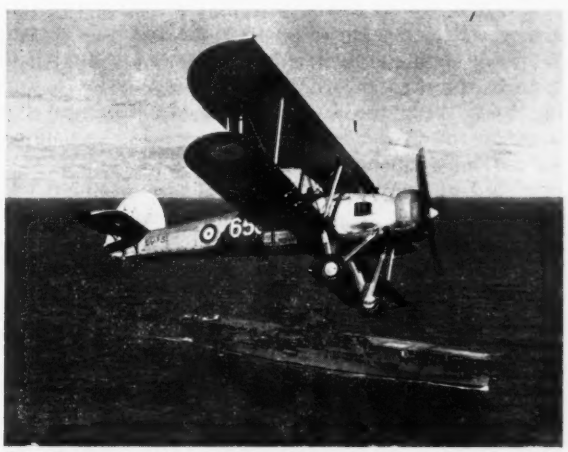
Further excellent experience came with an order to build one hundred of the famous Sopwith 1½ Strutters. Richard Fairey was not only learning fast by the practical urgency of the demands of the first war in which aircraft were used, but he found himself plunged into the throes of the constant expansion of works and men necessitated by those demands. He had to know everything in those days, from aircraft design to works organisation, from understanding the mentality of Government customers to solving the aerodynamic, structural, maintenance and repair problems which were endlessly waiting for immediate solutions. It was an experience, as it was for all young aircraft firms which were to expand to unbelievable proportions only twenty years later, after surviving the order-starvations of the twenties. Fairey was then, and for years afterwards, in and out of the drawing office far more often than was expected of managing directors.

He had become convinced before the First World War ended that the most urgent problem to be solved was to find a way of increasing the speed range and the lift.

In June 1916 he produced the variable camber wing, the essence of which was a flap, hinged on the rear spar, and running along the whole length except for the ailerons, which were differentially controlled. The pilot had a handwheel to enable him to adjust the flaps. The pressure distribution did not follow expectations, and heavy strains came on the operating gear, but finally difficulties were overcome, and many aircraft were produced using the variable camber wing. In 1936 Fairey was awarded the Wakefield Gold Medal of the Royal Aeronautical Society, for his invention.

The first machine to be designed and built by the Company was the twin-engined fighter, the F2. The works began with a wooden shed taken over from the Army Motor Lorry Company in Hayes. The first Naval machine was the Campania which began as a two-seater reconnaissance seaplane. It had a Rolls-Royce Eagle engine and ended as a three-seater with the same engine.

The long-range monoplane (Napier Lion) which set up a World's Distance Record in February 1933 by flying from Cranwell to Walvis Bay, non-stop, a distance of 5,309 miles in 57 hr. 25 min.



The Fairey Swordfish 1935, which served throughout the War in many roles.

It is inappropriate here to consider in any detail the work and progress of the firm which Richard Fairey founded and directed to within a short time of his death. The part he played and the progress that was made is summarised best in his own words.

In a speech on 24th November 1955 he said, "This is the 40th Anniversary year. The first factory, consisting of five wooden sheds on the site where the Hayes plant now stands, cost £807 6s. 8d. The first offices, a brick building, still stands. . . .

"During the past 40 years we have designed and built 109 different marks of aircraft, of which 48 were distinct types, ranging from small single-seaters to four-engined flying boats. . . . I think that we can claim that the remarkable Fairey Fox of 1925 altered the whole trend of design of military aircraft."

In a lecture to the Royal United Services Institution in February 1931, he spoke of the genesis of the Fox. "In 1921, when it was desired to find a replacement for the DH.9A, the specifications asked for a speed less by 6 m.p.h. than that of the obsolete machine. The result was the Fairey Fawn, an inferior machine, after spending five years and much money. At this period the Air Ministry was not giving the designer a sufficiently free hand. I therefore took the Fawn specification as representing the Staff requirements and had built a type to those requirements from the designer's point of view without any restrictions other than those directed by common sense. Perhaps in that matter the designer had too much of his own way! Still it set a new standard for two-seaters which was higher than the existing standard for single-seaters."

Captain Norman Macmillan, who was Fairey's chief test pilot, demonstrated the Fox to Sir Hugh Trenchard, who was the Chief of the Air Staff at the time. Writing in *The Aeroplane* in the 40th Anniversary year, he said, "I remember the occasion as if it were yesterday. After my flight demonstration the Chief of the Air Staff asked me to accompany him apart from all the others and we walked out on the grass of the airfield well out of earshot. There the C.A.S. asked me what I really thought of the Fox; did I think it was an aeroplane that could be handled safely by young and less experienced pilots of the R.A.F.? I told him frankly it was one of the easiest and most viceless aeroplanes I had ever flown. We walked back to the hardstand and Sir Hugh Trenchard looked at Dick Fairey and said in his booming bass: "Mr. Fairey I have decided to order a squadron of Foxes." Looking back with an unprejudiced mind, there is no doubt that the Fairey Fox produced an impact on British military aviation. It forced progress which had become stagnant, and in a short time, speed, which had remained unchanged for many years, except to slow down, was almost doubled. And this was achieved with little increase of power. The secret lay in aerodynamic design which absorbed far less power than ever before in R.A.F. history. If Richard Fairey had no other achievement to his credit that one alone would serve to perpetuate his name in aviation history."

His chief designer at the time was M. Lobelle, and with him that brilliant mind—P. A. Ralli.

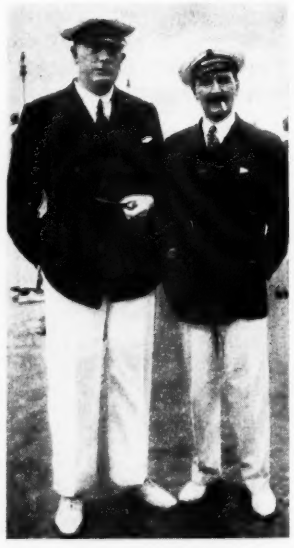
Fairey, in his 1955 Annual General Meeting speech, his last one on these occasions, added, after his general review, of the Fox and other machines: "We have pioneered not only aircraft but, for example, such things as variable pitch propellers, stressed skin structures, and the first free coupled engine. And we are still pioneering today in guided weapons, hydraulic control apparatus, precision casting and the specialised application of plastics and other new production methods. . . . Today we are developing the largest helicopter and the smallest helicopter, and what we believe to be the fastest aeroplane."

And how proud he was when his belief was confirmed when the Delta 2 flew at over 1,100 m.p.h. and obtained the World's Speed Record. On 26th April 1956, a bare five months before he died, he made a trenchant, vigorous speech which showed he had lost none of that great Elizabethan spirit which had come down to him from his forefathers.

"I am glad to say, in these days when it has become fashionable to criticise the British aircraft industry, that this recent record has silenced the critics and brought most generous tributes in their place. . . . It was true that as an industry we lack the almost awe-inspiring equipment which is available for the American aircraft industry—vast wind tunnels, supersonic and hypersonic; test chambers of enormous ranges of altitude and temperature; and runways some 20 miles in length. We lack these things, but we have the speed record. Indeed we also have the height record taken by Wing Commander Gibb on a Bristol-engined Canberra last year. Additionally, Great Britain holds the land speed record and the water speed record and thus I see no reason why as an engineering country we should humbly accept second place . . . ."

In 1922 he was elected President of the Society of British Aircraft Constructors, a position he held until 1924. In 1923 he became a member of Council of the Aeronautical Society, upon which he served, save for a break of one year, until 1936.

The severe setbacks to the aircraft industry, due to lack of Government orders and the Government economy axe, had had its repercussions on the Society's membership. But by 1923 the slump was reflected in its income. The deficits were such that the Secretary resigned and a member of Council was asked to act as Honorary Secretary.



Richard Fairey with M. Louis Breguet at Deauville, August 1927.

It was mainly through Fairey's influence that an annual grant was made by the S.B.A.C. to the Society to help it in its difficulties. It is a generous grant which has now been made for over thirty years, without any conditions as to its spending. In many ways over the next few lean years Fairey himself contributed to the Society's funds, in the best way of all it seemed then, by paying the bills for those functions which the Society had to undertake to ensure its prestige in those difficult times. He would never allow the Secretary to skimp any function just because the Society could not afford it. As a personal note I must record here that I had to consider my own position as the Secretary in the early 1930's, for there were expenses to which I had committed myself before becoming Secretary. Fairey learnt, through a member of Council, that I was contemplating resigning and insisted on paying the expenses the Society then could not have paid by an increase of salary.

Richard Fairey was elected President of the Society on 30th May 1930. In the summary of the year's activities published in December 1931 there appeared an appreciation of Fairey's help, ending with the words "Mr. Fairey's first year of office has coincided with one of the most severe financial depressions this country has experienced, but his generous help has enabled the Society to come through with its finances unimpaired."

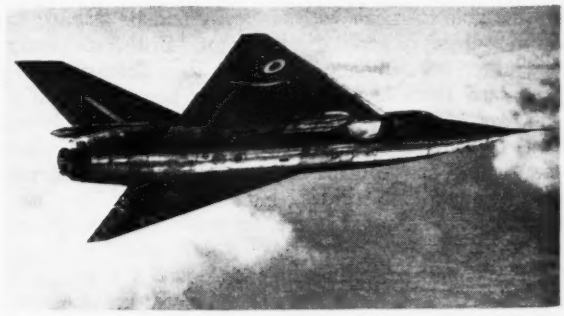
If there ever was a fairy godfather in the anxious years of building, Richard Fairey was that godfather of the Aeronautical Society. He always felt that the success and prestige of the Society must depend upon a flourishing technical membership, and in reply to a suggestion of mine he wrote, in April 1927, "I have made it a rule among my technical staff that for anyone who will sit for the Associate Fellowship examination and pass it, I will pay the whole expenses, plus entrance fee and one year's subscription."

This was a powerful addition to the Society's funds and membership, an example quickly followed by T. M. Sopwith, of the Hawker Engineering Company; Commander J. Bird, of Supermarine's; Mr. J. Siddeley, of Armstrong Whitworth's; C. C. Walker, of de Havilland's; and Mr. Thomas, of Bristol's.

The Council early recognised the importance of creating an Endowment Fund which would provide a steady income the Society could use as required. But the years immediately following the First World War were not conducive to the raising of considerable funds. Fairey, despite the difficulties, managed to increase the fund considerably while he was on the Council. In 1937 he contributed £10,000, in a seven year deed, to the Fund, giving a lead which ultimately was generously followed by many members of the aircraft industry.

The twenties and early thirties were years of great air achievements, not only in flying, but in research and development. In 1931, Lord Amulree suggested to Fairey, as the President, that the Society should found a special medal for important achievements leading to advancement in aeronautics.

Medals cost a considerable sum of money to found, for there are the designs to be made by a medal expert, and the steel dies from the drawings and so on. Fairey



The Fairey Delta 2 (Rolls-Royce Avon), which set up a World's Speed Record for Great Britain, flown by Mr. Peter Twiss, on 10th March 1956, of 1,132 m.p.h.

undertook to pay the whole of the heavy cost of what are now known as the British Gold and Silver Medals for Aeronautics. The first awards were made in 1933, and the list of recipients includes some of the most famous names in British aviation. Fairey very rightly suggested that the designs of the medals should themselves commemorate early achievements in the history of British aeronautics. The Gold Medal, with its portrait of Sir George Cayley and his model aeroplane of 1804, commemorates the Father of British aeronautics; the Silver Medal commemorates the work of Henson and his machine of 1842 and of John Stringfellow's model of 1848.

Many members of the Society will remember the Great West Aerodrome, the flying field of the Fairey Aviation Company, now submerged by London Airport. On 5th May 1935, Richard Fairey gave the Society the free use of the aerodrome for the first of a series of Flying Garden Parties to be held on it. He paid all the expenses involved and provided the additional staff and organisation required so that the Society would not find itself facing heavy bills. Some fifteen hundred members and their guests attended, and its success was evidenced by the fact the attendance increased every year, until in 1939 it had reached over 6,000.

During the Second World War, Sir Richard was in America as head of the British Air Commission. In 1942 he received his knighthood for his work in Washington. The task which he undertook taxed his energies to the full and strained his heart. An operation, which prolonged his life for some years, nevertheless forced him to take life more slowly and carefully.

Sir Richard never became reconciled to the compulsory acquisition of the Great West Aerodrome, for he had not been able to protest at the time. In 1949 the Society again enjoyed the hospitality of an aerodrome under his aegis at White Waltham, and again in 1950 and 1951.

Fairey had "a heart with English instinct fraught," and on many public occasions he did not hesitate to show that heart to the world. In January 1922 he spoke of the drastic cuts in the Air estimates.

"It had always been axiomatic that Great Britain must rely upon her own strong right arm and not upon the goodwill of her neighbours. If this country once establishes itself as the first Air Power in the world, it

will be able to speak with authority and be listened to on the subject of aerial disarmament. British air power had never been intended for other than defensive purposes and there had never been any suggestion that it will ever constitute a danger to other nations by being used for offensive purposes. . . . They were told that they would starve in three months if the Navy could not hold the sea routes, but if they lost the first advantage in an aerial attack, the war will not last three months."

He could be biting on occasion. "These pale intellectuals who don't deserve their own country," he said of those who had been running down the land in which they lived, and of some builders in between the wars, "These miserable hucksters of jerry builders who pawn the countryside for a mess of cottages."

In a speech he made in January 1927 on Aviation, he said bluntly, "I have been frank and have suffered for it. A man is expected to make a conventional, standardised speech in this country, otherwise he was a 'Red' or what Mr. Lansbury would term 'hard-faced.' Well, it is better than being sloppy faced."

On occasion he spoke in very moving terms. On 22nd December 1949, he and his fellow directors entertained nearly 300 guests. They were employees who had served the Company for over a quarter of a century, many for over thirty years.

"I am not one of those who ordinarily flinch at the ordeal of public speaking," he began his speech on that occasion. "Never have I been so anxious to make a good speech and never have I felt so inadequate to do so," and continued,

"When a large body of men and women hundreds strong have spent their lives in the same service in close company with each other working to the same ends, suffering the same triumphs and disappointments, it forms a bond between us hardly equalled by any other human experience. We have been together for what is virtually a lifetime. . . . We have had a common object, a common interest and a common purpose throughout our lives and we become thereby a family, held together by bonds and feelings which the passage of time can only tighten."

Fairey was an all-round sportsman, a first class shot, fisherman, and helmsman. He was the great country squire and, in another age, would have raised his own regiment of horse, or sailed the seven seas to the terror of the Queen's enemies. There is a great affinity between sailing and flying, both technically and psychologically, and many leading figures in the aeronautical world have become as well-known in yachting circles. He was a member of a number of yacht clubs and Commodore of the London Yacht Club.

He was, however, not always prepared to accept things as they are, just because they had always been that way. He was a man of great independence of mind, one who wanted to know Why even more than How. When he gave his mind seriously to yachting he could see no reason why he shouldn't be able to take the wind out of the sails of his competitors, by using the wind tunnel to find out how he could put more wind into his own sails. When his chief aerodynamicist had

One of the last photographs to be taken of Sir Richard Fairey —at Bermuda.

obtained the results of various settings of sails on the yacht model, Fairey asked one of the leading helmsmen, whose skill was unquestioned, to look at the model, and to set the sails to get the best results.

He set them exactly as the wind tunnel results showed they should be set! The wind tunnel experiments on sails then stopped.

Fairey was a man of great personal courage. "As a physician of his who had the privilege of advising and treating him for more than a decade," wrote the American Dr. Paul D. White, "I wish to pay tribute to his great courage and patient endurance in the face of illness which would early have crippled a less stout-hearted man. At the end he accepted the risk of an essential operation hoping that he might survive to continue his career to help others."

Sir Richard Fairey was a great President of the Royal Aeronautical Society. In his heyday he served it, guarded it, gave it of his own great heart, and left it strengthened beyond measure. His name will loom large in its annals.

"How beautiful is the battle,
How splendid are the spears,
When our banner is the sky
And our watchword *Liberty*
And our kingdom lifted high above the years.

"How purple shall our blood be,
How glorious our scars,
When we lie here in the night
With our faces full of light,
And death upon them smiling at the stars."

ALFRED NOYES.

J. LAURENCE PRITCHARD.

The First Sir Henry Royce Memorial Lecture

Sir Henry Royce, Bart

by

IVAN EVERNDEN, M.B.E., B.Sc.(Lond.), M.I.Mech.E., M.S.A.E., M.S.I.A.

(Rolls-Royce Ltd., Motor Car Division, Crewe)

The 996th Lecture to be given before the Society and the 26th Main Lecture to be held at a Branch of the Society, was also the First Sir Henry Royce Memorial Lecture inaugurated by the Derby Branch. The Lecture, "Sir Henry Royce, Bart," was given by Mr. Ivan Evernden, M.B.E., B.Sc.(Lond.), M.I.Mech.E., M.S.A.E., M.S.I.A., on 1st October 1956 at Derby. Mr. A. A. Rubbra, F.R.Ae.S., Chairman of the Derby Branch opened the Meeting and Dr. E. S. Moult, B.Sc.(Eng.), F.R.Ae.S., Vice-President of the Society, presided for the rest of the meeting.

MR. A. A. RUBBRA (Branch Chairman): This was a momentous occasion for the Derby Branch of the Royal Aeronautical Society. He had been going to use the term "unique" and, while that was true about this particular Lecture, they had in fact been honoured by a Main Meeting of the Society in Derby on one occasion previously. He would like to say on behalf of the Branch how much they appreciated that honour and privilege. He had an apology to make on behalf of the President, who unfortunately had been prevented at the last minute from attending the meeting. They were fortunate, however, in having with them a Vice-President of the Society, Dr. E. S. Moult. On behalf of the Branch he extended a hearty welcome to Dr. Moult and to the various officers and members of the Society who were present and also to the representatives of the various Branches. Dr. Moult was known personally by many and by repute to many more and he needed no introduction. He had great pleasure in handing over the meeting to him.

DR. E. S. MOULT (*Fellow*): Before starting the proceedings, he would refer to two sad events of the day. Most of the audience would have heard that another great pioneer, Sir Richard Fairey, had died. Sir Richard had suffered a great deal in the past few years and he died the previous night. Also they had just received the news of the loss of the Vulcan when landing at London Airport after its return from Australia with, he was sorry to say, loss of life. He thought it would be fitting if the audience would stand for a few moments in silent honour to these people.

The President had asked him to express his profound regrets that he could not be present on this occasion: it was most unexpected. He had looked forward a great deal to the meeting and the same applied to the other Vice-Presidents, particularly to Mr. George Edwards who, as they knew, was President-elect. It was the policy of the Society to found and support a number of Memorial Lectures to distinguished engineers and scientists in the field of aeronautics. By custom these lectures were held, if possible, in the headquarters of the field of activity of the person concerned. Thus they had the Rex Pierson Lecture at Weybridge; the Roy Chadwick Lecture at Manchester; the Barnwell Lecture at Bristol, and others. It was therefore very right and proper that the name of Sir Henry Royce should be associated for all time with Derby. Again by tradition, the first Memorial Lecture was regarded as a Main Lecture of the Society and as many members as possible came out "on location." The purpose of this was two-fold; firstly, because the occasion deserved it and secondly, because it brought headquarters and the Branch closer together, which was a very good thing. There were present various members of Council; Mr. N. E. Rowe, the President of last year; Major Bulman, a Past-President who was now Honorary Treasurer; Mr. Handel Davies, Chairman of the Branches Committee; Professor Baxter; Air Commodore Banks, and Mr. F. M. Owner. They had visiting members from something like twelve Branches together with representatives of the Institution of Mechanical Engineers. The Society was very pleased at this excellent support. It was, indeed, unfortunate that Lord Hives—who was in America—could not be present and also that circumstances had prevented Mr. Elliott from being with them.

The Lecture to the memory of Sir Henry Royce would be given by Mr. Evernden, who was well known to his colleagues in Derby and Crewe. Mr. Evernden took his degree at King's College, London; he was a Member of the Institution of Mechanical Engineers and of various other professional bodies. Mr. Evernden began his association with Rolls-Royce no less than forty years ago, when, in 1916, he joined the firm as a junior draughtsman. He soon became a senior draughtsman and spent—perhaps significantly—two years in the airship drawing office. After a period in the chassis design office, Mr. Evernden moved to West Wittering where he worked as a senior designer directly for and with Sir Henry Royce. Over a period of twelve years Mr. Evernden came to know Sir Henry and his works as well as any man and it was fitting that he should give the First Memorial Lecture to Sir Henry Royce.

PART I

I FIRST MET Mr. Royce in the summer of the year 1917, at St. Margaret's Bay, near Dover. From that time, until his death in 1933, I was privileged first to work for him and later, with him. During those sixteen memorable years, the manifestation of his uncanny gifts of accurate observation and logical deduction never ceased to astound me. Eccentric and somewhat incomprehensible as he was, I grew up regarding him almost as a father.

For this reason, I am very honoured that your Society should have accorded me the privilege of telling my story of his life, by giving the first Sir Henry Royce Memorial Lecture. I approach this task with a sense of grave responsibility; so great is the occasion and so important the subject.

Although your Society's interest will be chiefly in the contribution which Royce made to the progress of aviation, it is necessary to study this against the background of his early life, and his equally outstanding contribution to the motor car industry.

One morning in April 1933, with a few of his closer associates, I stood on the lawn of his house, as our great chief was taken from us. Just 70 years before, in March 1863, James Royce, a miller, in the little village

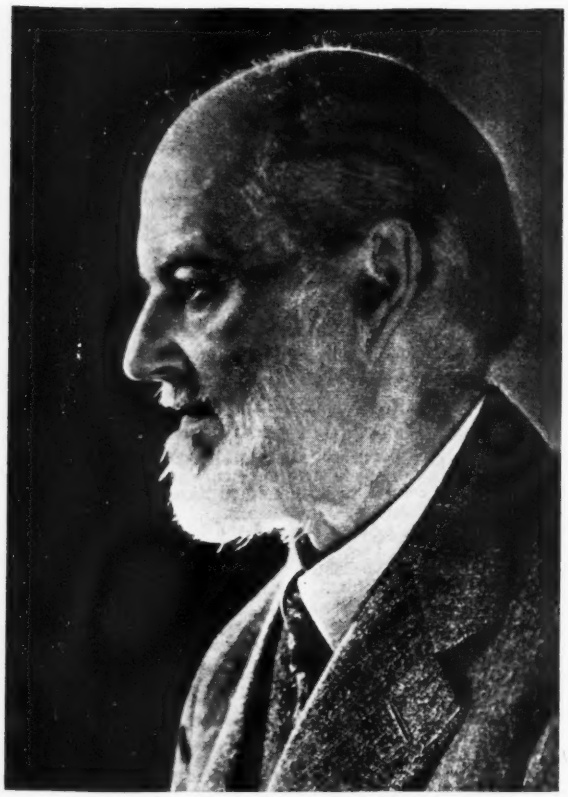


FIGURE 1. Sir Henry Royce, Bart.

of Alwalton, near Peterborough, was told of the birth of a fifth child, who was baptised in the village church in the July of that year with the names of "Frederick Henry."

It is impossible for me to condense in the customary manner the story of his early life . . . "He was educated at such and such a school and later went to a college to study engineering . . ." Life was not so ordered in those days and certainly not for young Royce. Education in the very rural area of Alwalton was not easily acquired and by the time Royce was nine years old he had spent only one year at school. His father's business as a miller had failed. Leaving his wife to take care of herself, James Royce set out for London with his two sons, where Henry helped to swell the family purse by selling newspapers for W. H. Smith & Sons. When Henry was but nine years old, his father died, and he was left to the care of his mother, his relatives and friends. An aunt at Fletton eventually paid for his apprenticeship to the Great Northern Railway, and he entered the works at Peterborough in the year 1877. He had always shown a great liking for machinery and here he was able to develop his gift as a mechanic.

In this, he was helped in no small measure by the Mr. Yarrow with whom he lived, who had a small private workshop with a lathe. Three years later, his aunt died and his apprenticeship ended abruptly. Royce set out for the North, armed with an excellent recommendation from his late chief, only to find work hard to obtain owing to the industrial depression. However, he found employment with a firm of tool makers in Leeds, where again he could develop his bent as a mechanic.

Failure soon befell this concern and Royce was back in London, lodging in Kentish Town and working for the Electric Light & Power Co. who were pioneering in the lighting of streets and public buildings. It must have been here that he acquired a love for that new source of power—electricity—which he at once proceeded to study in his meagre leisure at night school. Such was the time in which he lived and his ability to learn quickly, that he was sent by his employers to be "First Electrician" to their subsidiary company in Liverpool.

He has told me many stories of the adventures of those days. On one occasion he was lighting a large hall for a public function, when the tension of the belt between the engine flywheel and the dynamo pulley gradually faded, only to be restored by the judicious application of a wet rag to the outside of the belt until, at a convenient interval, he could "shut down" for a few minutes.

Unfortunately, this company failed in its pioneer work, like many others of its kind, and Royce was again unemployed. Although fortune seemed ever to stack her odds against him, in one respect that was not always so. Several times in his life, he was lucky to meet just the right person at the right time. This time it was to be Mr. Albert Claremont, who, recognising his ability as a mechanic and electrician, lent him £50, which, with his own £20, enabled him to start a small business in Cooke Street, Manchester, for the making of electric bells, lamps and fitments.

Entirely by the incessant effort of Royce, the business grew rapidly and extended into the manufacture of dynamos, motors and cranes, which soon acquired a very high reputation. In the year 1894, a company called "F. H. Royce & Co., Electrical and Mechanical Engineers" was formed and this thrived for five years, when the depression due to the Boer War set in.

Royce, who was living at Knutsford, had bought a Decauville car, which caused him considerable annoyance owing to its lack of reliability and refinement. These failings he proceeded to rectify, much to the dismay of his partner who was struggling to keep the business alive. Motoring as a sport had existed on the Continent for some years, but had not until then spread to this country.

To the further dismay of his partner, Royce announced his intention of building a two-cylinder motor car and, to this proposal, his partner agreed, even though somewhat hesitantly.

This car embodied all the designer's love of good mechanics, and the novel ignition system which he used was no doubt a child of his electrical experience. Years later, he said to me, "Electricity itself is most reliable,

it is the mechanism which goes with it that gives all the trouble; generally speaking, electricians are poor mechanics."

At this time in London there was a firm headed by the Hon. C. S. Rolls, the pioneer balloonist and racing motorist, engaged in the business of the sale of continental cars in this country.

In the year 1904, one of the early Royce cars, owned by an enthusiastic motorist by the name of Henry Edmunds, was shown to Rolls, who was so impressed by its outstanding qualities that the same year, after some considerable difficulty, a meeting was arranged between Rolls and Royce at an hotel in Manchester. Again Royce met the right man, at the right time.

Rolls agreed to sell all the cars which Royce could make and he outlined a range for four models, all of which subsequently were produced, and which bore the name of "Rolls-Royce." A 20 h.p. Rolls-Royce was entered in the Tourist Trophy Race of 1905, gaining second place. The following year it won.

It was fortunate for Royce that the Hon. C. S. Rolls had with him as partner in his business, Mr. Claude Johnson, one of the founders of the Automobile Club, and its first Secretary. Later, under the patronage of King Edward VII, it became the Royal Automobile Club. Just as Royce was to become famous as an engineering genius, so Claude Johnson was to become famous for his foresight, his organising ability and his unique flare for high-class salesmanship.

Largely due to the enthusiastic efforts of a certain Mr. Briggs, who provided financial backing for what in those days was a rather pioneering venture, the Company of Rolls-Royce Ltd., was formed in March 1906, under the directorate of F. H. Royce, C. S. Rolls, A. W. Claremont, Claude Johnson and A. H. Briggs, with a capital of £60,000.

Knowing Royce as I did, I can well imagine the long hours of hard work and concentrated effort that he and his loyal team had put in to achieve such rapid progress. Nothing would be left to chance, and every move considered and reconsidered. Speed with care and consideration entails long hours of exhausting mental and physical effort.

After the earlier Tourist Trophy, there followed a series of victories in Reliability Trials and Record Journeys, the accent in each case being on reliability with silent and smooth travel. Rolls was able to sell all the cars that Royce could produce.

Claude Johnson, the master of strategy both in salesmanship and in the handling of Royce, quickly realised the desirability of a one-car policy in order to relieve Royce, upon whom the strain had begun to tell, and to achieve the necessary volume of production.

Likewise, he realised that Cooke Street was too small for the programme he had envisaged. So, in 1906, increased capital was acquired, again only by the generosity of Mr. Briggs, and to Royce fell the task of designing a new and ideal factory to be built at Derby. As if that burden were not enough, that Autumn Royce began the design of the car which eventually was to become the famous Silver Ghost. Perhaps the most

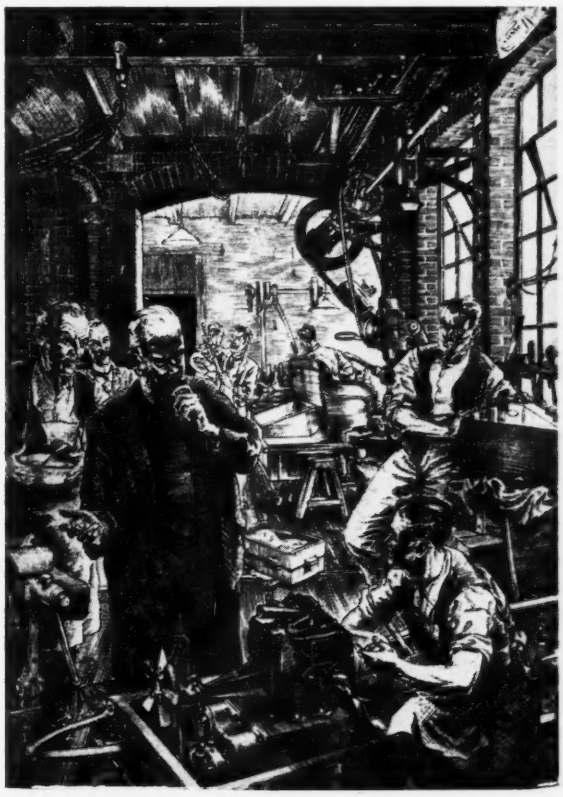


FIGURE 2. F. H. Royce at Cooke Street, Manchester.

significant period in the career of Royce and of the company which he founded, was that period dating from the opening of the Derby Works in 1908 to the outbreak of the First World War in 1914.

Beginning with the 15,000 miles Reliability Trial under R.A.C. observation in 1907, success upon success was heaped upon the Silver Ghost which had earned the epithet, "The Best Car in the World". All this happened in the short space of less than 10 years.

How was this made possible? Firstly by Royce, who was happy only when he was striving to make something a little more nearly perfect. Left alone, he might have remained unknown and have become a commercial failure, by diffusing his energy without a thought of financial gain, either for himself or his company. Secondly through the guiding genius of Claude Johnson, who realised that Royce could produce something finer than had ever before been made, and that this could become the corner stone of his sales policy. It is, I believe, the only instance in which "Idealism" has been used to make a profit.

After the vicissitudes of his earlier career, one would have expected that success heralded the end of misfortune for Mr. Royce. However, it was not to be so.

The Hon. C. S. Rolls, restless, impulsive and for ever seeking new adventures, became tired of motoring and took up flying; this time not in balloons or lighter-than-air machines, but in the aeroplane. This he said

he found most refreshing and gave to him a new sense of life. He quickly learned to fly and purchased a machine of his own from the famous Wright Brothers, whom he met soon after the opening of the Derby Works in 1908. Within a year his reputation as a flyer equalled that which he had acquired as a motorist, in which role he rapidly lost interest. His great achievement as an aviator was to make the first double crossing of the English Channel.

A few months later, on 12th July 1910, at a flying meeting in Bournemouth, when competing in landing in a " Box " contest, the tailplane of the aircraft broke off and the machine crashed. Rolls died a few moments later.

This incident had a profound effect on Royce who had a rooted objection to pioneering. Although Rolls had no doubt endeavoured to interest him in the mechanics of this new form of transport, Royce had strenuously resisted.

Now he looked upon the aeroplane as having robbed him of his great colleague and collaborator. He gave no thought to the aero-engine until six years later, when war thrust it before him. But for that unfortunate accident at Bournemouth, there might have been a different story to tell.

Perfection and idealism in the design and manufacture of a motor car is praiseworthy but it is a luxury which only a few can afford. But these qualities are essential in an aircraft. Consequently, it was this industry that held great opportunities for the full growth of his genius. Had the fate of war not intervened, it was inevitable that sooner or later he would have turned his attention to the aero-engine.

Fate had not yet delivered its last blow. The years of incessant toil with inadequate meals and insufficient rest and relaxation, which began in those early days in Manchester, and was only alleviated in the later years through the fatherly care of C.J., had taken their toll of his physical strength and Royce became seriously ill.

Realising all that was at stake, C.J. took control, and Royce was taken to specialists in London. Although every effort, no matter how great, was made to restore him to health, the doctors could hold out little hope. Largely due to Royce's persistent willpower, he gradually recovered strength.

Again C.J. took no risks. After taking Royce through France and Italy, they wintered in Egypt, and in the Spring went to the South of France.

Here, at Le Canadel, C.J. built a villa for Royce in which he could spend his winters. He also acquired a residence in Crowborough, Sussex, for him to occupy in the summer. The great man was never to go back to Derby and the battle of industrial life. Instead, he was to gather around him a few chosen people with whom he could carry on his work of perfecting mechanisms. Close to the Villa Mimosa at Le Canadel, there was built an office to house the staff—the Bureau. The first occupant was Mr. A. G. Elliott, C.B.E., late Vice-Chairman of Rolls-Royce, and erstwhile Chief Engineer, and also Mr. Maurice Olley, later to become famous in the automobile industry of the U.S.A.

Next C.J. found Royce a permanent home in England at St. Margaret's Bay, near Dover. The house, named Seaton, was about half way down the winding road to the bay, with a beautiful view from the cliffs across the Channel to France.

Incidentally, this house, I understand, was completely demolished by enemy action in the Second World War, the only one so to suffer in the tiny village.

Just when life for Royce at last appeared to have become settled, and secure, Fate struck another blow. Royce was taken seriously ill in December 1912, when at Le Canadel, and had to be rushed to England for a major internal operation. Again the fatherly care of C.J. and the indomitable courage of Royce won the battle for life, but it was obvious that very great care would be necessary if this valuable life were to be preserved. From the nursing home at Overstrand where Royce had recuperated from his earlier illness, C.J. obtained a nurse to keep constant watch over the Great Man, and Miss Ethel Aubin stayed with him until he died.

In an address to Aeronautical Engineers, such a detailed account of the early life of Mr. Royce and the birth of the motor car industry which he founded may seem out of place. However, I have given it to make two vital points.

The first is the fact that every event in his life during that period had a profound effect on the development of his genius. The misfortunes of his childhood and early youth, although depriving him of the education he might rightly have deserved, had the virtue of forcing him to become first a mechanic, then an engineer. This is a method of approach which, until recently, has been growing less in favour and more difficult to pursue. I am glad, therefore, that the scheme of technical education for engineering personnel in the plant, sponsored so vigorously by Lord Hives, who, as " Hs," was for so many years the complement of Royce, now is a reality.

It is a grim thought that, with our present system of education, where children are fed with knowledge, filtered at intervals, and the residue passed off through selected channels, dependent upon the results of an examination, Royce might have failed at the first filter, and would never have risen above the rank of a mechanic. This is equally true of other similar great men, like Henry Ford and Lord Nuffield.

The second fact is, that had not Royce and his associate, Claude Johnson, built up the motor car engineering firm of Rolls-Royce, and gathered together such people as Ernest Hives, Tom Haldenby, Eric Platford, Arthur Wormald, A. G. Elliott, to mention only a few, there would not have existed in 1914, the organisation to design and develop, in but a few years, the aero-engines which were to play such an important part in bringing victory to this country in the 1914-18 War.

PART II

Apart from his genius, and probably in no small degree due to the events of his earlier life, F. H. Royce

was a unique personality. Tall and erect in appearance, he had the shape of head which we associate with a scholar and which resembled that of the late Sir Oliver Lodge. In his days at Manchester and Derby, he had been a great task master, expecting from his workmates the same devotion to the job that he himself would give. He was intolerant and of hasty temper. He would instantly dismiss a bench hand for the incorrect use of a file. The next day, having forgotten, and finding him absent, he would send for him to come back.

He never took part in any pastime or sport; his recreation had been his work. Although he married in 1905, he had no children. Later I formed the opinion that his attitude towards life might have been modified if he had been blessed with a family, for he was uncannily popular with children and had a way of charming them. He did not smoke and in those days did not "drink" strong beverages. Although he made the "Best Car in the World", he never motored for pleasure—except for the thrill of trying out some new feature of design.

This is the picture of Royce in the last few months before the world was to be torn asunder by the factions of War.

PART III

Having declared war on Germany, on 4th August 1914, the Government apparently had no very clear idea of the part the motor car and the aeroplane could play in the struggle, or even of the contribution that could be made by the new industries they had created. Armament manufacture was confined largely to armament firms. Some people honestly believed that the motor car and the aeroplane could be of little use in war. However, it was obvious to some that the motor car could and would have to play an important part in the conflict, and very soon motor cars were provided for Staff use. Many Rolls-Royce cars were rebuilt as armoured cars.

This alone could not keep the Derby Factory fully occupied and many of the personnel joined the Forces, in some cases only to be brought back later.

After making "Flechettes" for dropping from aircraft, and shells, the Company was asked to manufacture the Renault Aero Engine. This was one of the most successful of its kind in France, "V" 8 in design it was air-cooled, and had a capacity of 9·44 litres, and was rated at 80 h.p. at 1,800 r.p.m.

This engine was used in a few small scouting airships of the non-rigid type, operated chiefly by the Navy, and in the B.E.2.C. aeroplane, of the Royal Flying Corps. Soon after this a similar engine, the RAF.1A was also produced.

It was inevitable that Royce and his team would not rest contented for long with the making of engines, the design of which offended the very tenets of their doctrine of perfection.

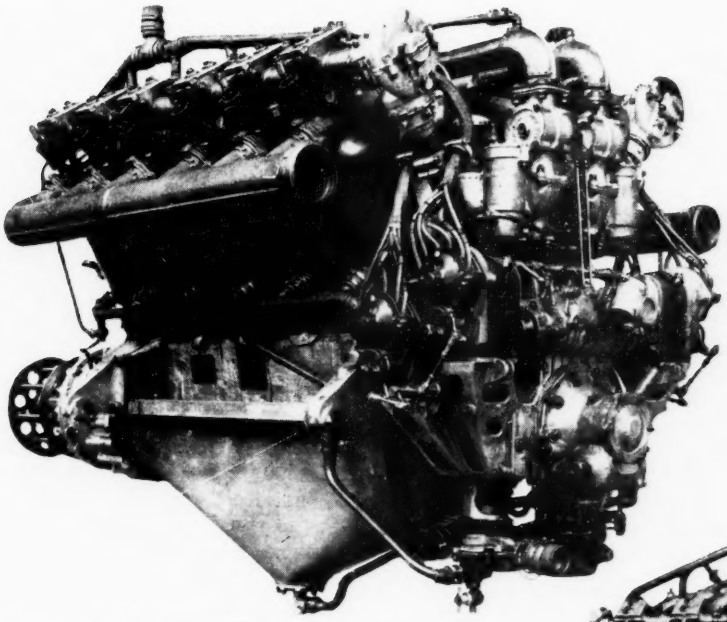


FIGURE 4. Eagle Services VIII (Rear).

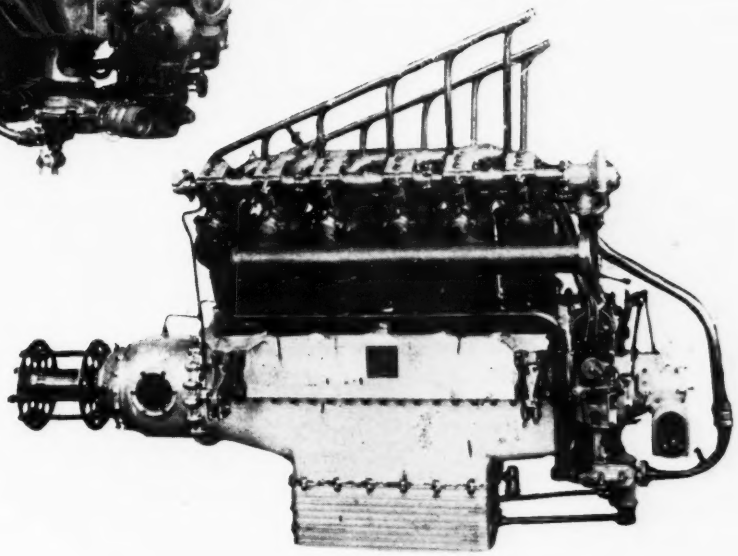


FIGURE 3. Eagle engine—Pre Series I.

At this time, Royce was at St. Margaret's Bay, with his small staff of enthusiasts, including A. G. Elliott and Maurice Olley.

As early as August 1914, design work started on a Rolls-Royce Aero Engine, having 12 liquid-cooled cylinders, set in a 60° V. formation and having a cubic capacity of 20·32 litres. A special feature of this engine was the construction of its steel cylinder barrels, individually bolted to the light alloy crankcase and having pressed steel coolant jackets, made in halves, and gas-welded together and to the cylinder. Royce later told me that he had always admired this design which he first saw used on the early Mors cars.

This engine was expected to give 200 h.p. at 1,800 r.p.m.

Some idea of the rate at which the work proceeded can be gathered from the fact that the first prototype engine ran on the test bed in Derby in February, 1915.

E. W. Hives (now Lord Hives) was then in charge of the Experimental Department and it was a great day when he saw the engine first run and he could report to Royce that already it was developing 25 h.p. more than he had predicted. This engine, named the Eagle, was the first of a series to bear that illustrious name. The initial success of the design did not lull into complacency the team at Derby nor Royce at St. Margaret's Bay, and work went on incessantly to improve the power output, the specific consumption, the power to weight ratio and the usable life, in the true tradition of the breed to which it belonged. Eagle Series I, gave 240 to 270 h.p. at sea level at 1,700 r.p.m. By the time Series VII had been reached this figure had risen to 300 h.p. while Series VIII reached 360 h.p. The overall dimensions of the engine had not changed since Series I and the weight had increased only by 6·66 per cent. In all, close on 4,000 of these engines were built during the period 1914-18.

Perhaps the most notable application of the Eagle engine was to the Vickers Vimy Bomber. They were used also in the Handley Page Type 0/400 twin-engined bomber, and the D.H. 4.

This engine was also chosen for use in the 23 Class Rigid Airships which were being developed, and of which Rolls-Royce fathered or patented the power plant.

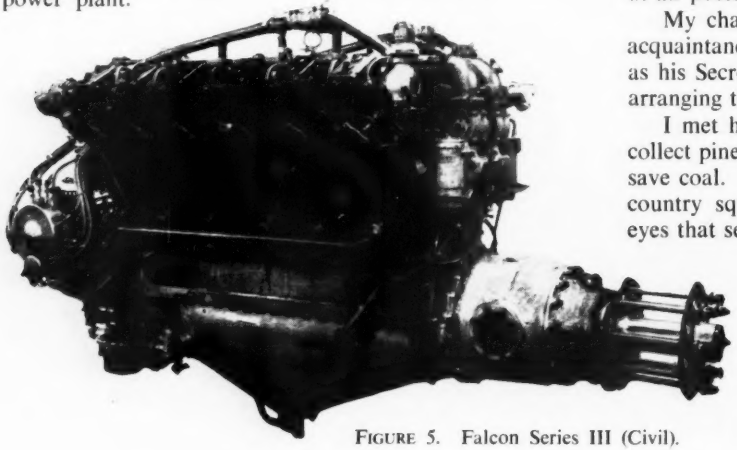


FIGURE 5. Falcon Series III (Civil).

FIGURE 6. Elmstead, West Wittering, Nr. Chichester, Sussex.

Almost in parallel with the design and development of the Eagle, design investigation had been proceeding on the Falcon. This was an engine almost identical in design to the Eagle, but of smaller capacity, being of only 14·22 litres. Falcon Series I gave 225 h.p. at 2,000 r.p.m., at sea level, while in Series III, the power had been increased to 270 h.p. Falcon engines were used in the D.H. 4, the Blackburn Kangaroo and exclusively in the famous Bristol Fighter during the First World War. It will be recalled that it was this machine which turned the tide of battle in our favour after the stalemate and stagnation in the trenches during the winter of 1917.

A third type of engine, the Hawk, a 6-cylinder in-line and virtually half a Falcon, was also produced in parallel with the other two engines. This was used in Non-Rigid Airships; the North Sea Ships, or S.S. Blimps, which did remarkably good work for the Navy in coastal patrols, spotting enemy submarines.

Early in 1916, I was directed to work for Rolls-Royce, Ltd., by the Ministry of Munitions, having completed part of a Degree Course in Engineering at King's College, London, and being not fit for overseas service in the forces. I joined the Airship Design Office at Derby and soon learned of the mythical yet powerful personality bearing the name of Royce. The more I learned of his work, his ideals and his teaching, the more determined I was to meet him and eventually, if at all possible, to become a member of his select team.

My chance came when in the summer of 1916, an acquaintance of mine went down to St. Margaret's Bay as his Secretary. I wasted no time in going down and arranging to be introduced to him.

I met him in the village, returning from a walk to collect pinecones for burning in the household grates to save coal. A tall and erect, genial man he was, like a country squire, with a soft voice and rather piercing eyes that seemed to look right inside one's mind and to read one's thoughts. So complete was the liaison between him and the Works that, from his conversation, it was obvious that he was fully conversant with everything that they were doing and hoped to do. During the conversation I had the opportunity of conveying to him my wish to work with him some day.

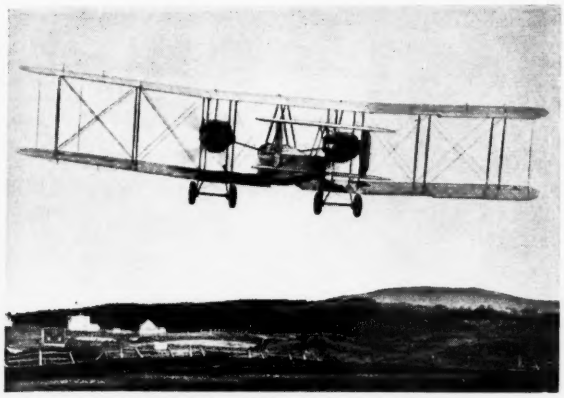


FIGURE 7. Vickers Vimy Bomber.

Not long after that time, life became rather hectic in the little village on the cliffs. Shells from long range guns crossed the Channel, aeroplane raids were made on the Channel fortifications and a nearby town, while coastal guns frequently fired across the bows of unidentified channel shipping. The military increased in number and food grew more scarce, while anti-invasion precautions caused Elliott to be arrested one night returning home late from work.

A new home was found for Royce and his staff at West Wittering, in Sussex, a very small village on the Channel, on the west point of Chichester Harbour, opposite to East Beach, Hayling Island, now well known to holiday makers and yachtsmen, but then little frequented.

The house "Elmstead" which was a rather long, two storey building, one room thick, with a wing each end, had a lovely old English lawn in front and a large garden, as well as several acres of meadowland.

Two small reception rooms were set aside for the design staff, headed by Mr. Elliott, and including Chas. Jenner and S. F. Pottinger. Upstairs was the Secretary's office, adjacent to the "Old Man's" bedroom—not always for us a convenient arrangement.

In the early days he was affectionately known as "Pa Royce" by all of his workpeople. In later years as a term of endearment, he was always spoken of by his staff as the "Old Man".

Here work continued unceasingly on the perfection of the Eagle and Falcon engines, involving modifications to extract more power from them and to increase their already amazing reliability.

In 1918 I was privileged to get a glimpse of this remote brain centre, when I was asked to join the staff. Arriving at Chichester around midday I made my way by carrier's van to the village and put up at the Dog and Duck, a tiny inn now closed. After tea, I was invited to go up to Elmstead for the evening. In the little office illuminated by large circular-wicked lamps, cream papered walls, and coconut matting floors, a conference was in progress on the design of the nose bearing of the Eagle epicyclic reduction gear.

The problem was to provide a means of rapidly setting this bearing in line with the crankshaft after an engine overhaul consisting of the fitting of new main bearings. The session ended only at 10 p.m. when Miss Aubin came in to suggest that it was getting very late. Then was evolved the double eccentric mounting for the nose bearing with vernier setting.

Royce had peculiar but always logical ideas. For instance I discovered that one worked in the morning, had several hours leisure in the afternoon, and after having tea with him at about 4.30 p.m., one worked on until 8 p.m. or even 10 p.m. His idea was that more benefit could be derived, especially during the shorter days, from leisure in hours of daylight when living in such a remote locality.

My stay was short, for the next day he sent me back to Derby, taking me to Chichester in his Silver Ghost—an unusual favour I thought until I discovered that he wanted to collect a battery from Adcock's Garage. As I was not very strong in health and had not been well he gave me three months leave of absence. Hard and ruthless as he could be, so also could he be extraordinarily kind and sympathetic. Sorry I was not to have made good—but with Royce one never knew. Although I had been groomed for the occasion under the experienced tutorship of Hs. I must have created a bad impression, or worn the wrong clothes.

PART IV

The period immediately following the Armistice in November 1918, held great problems for the management of the Company.

The war to end all wars had been won, and it seemed obvious that the demand for combat aircraft by this country, or any other for that matter, would be small. The future of civil aviation was still a debatable subject, on which strong views were held on either side.

The motor car, during the war period, had been developed beyond recognition by the United States of America, whose industries had been disrupted little by the conflict.

The decision of C.J. and Royce was that, in spite of the imperative task of re-establishing their eminent position in the motor car world, they were in the aero-engine business to stay.

During the latter part of the war, a new Rolls-Royce aero-engine had been designed, called the Condor. This engine was a larger version of the Eagle, which was thought to have reached about the limit of its power. The new engine had the usual forged steel cylinders, with welded steel coolant jackets, arranged in two banks of six cylinders of 60°V. formation. Novel features were the provision of an electric starter and a drive for a dynamo, and the use of four valves per cylinder, and two twelve-cylinder magnetos.

Series I and II of these engines never went into service in any numbers, as they were not available until after the signing of the Armistice.

It remained for this engine and the Eagle to make history in the post-war years.

Seven months after hostilities had ceased, a Vickers Vimy Bomber, powered by Eagle engines and piloted by Sir John Alcock and Sir Whitten Brown,

made the first crossing of the Atlantic. These intrepid pioneers were the first of a long line of enthusiasts who set out to put Great Britain "on the map" in civil aviation and the country honoured them justly with knighthoods.

That same year, the Smith brothers, Keith and Ross, achieved that notable flight from England to Australia in a similar machine.

In the August of that year a group of enthusiasts, calling themselves the Aircraft Transport and Travel Co., made aviation history in inaugurating a regular London to Paris service with a Handley Page machine powered by two Eagle engines.

The next year, Lieut. Col. H. A. Ryneveld and Flt. Lieut. C. J. Quintin Brand, flew in the Silver Queen to the Cape.

The development of the Eagle went on and by the end of 1922, design work on a Mark XV was in hand, but it was becoming apparent that its place as an engine of greater power had to be taken by the Condor, upon which design and development work was progressing both at West Wittering and Derby, slowly but surely.

This was an era of no great Government interest in aviation and development contracts were small and scarce. However, the Condor was chosen to power such new machines as the Fairey N.4 four-engined flying boat, and the Series III Condor, a moderate redesign having forked connecting rods was used in the Short Singapore Flying Boat.

In 1927, Series III.A Condor engines powered the Short Singapore Seaplane in which Sir Alan Cobham made his historic flight from England, across Africa, returning by the West Coast.

The next year, Royce had begun design work on the Condor Series III.B having a stronger crankcase, with longer main bearings and an increased diameter of crankshaft. This engine, which was available in 1930, was used in the Hawker Horsley, and the Blackburn Iris, a three-engined Flying Boat.

Perhaps it was most renowned for being the power unit of that very successful rigid airship, the R.100, which made the double crossing between England and Canada in 1930.

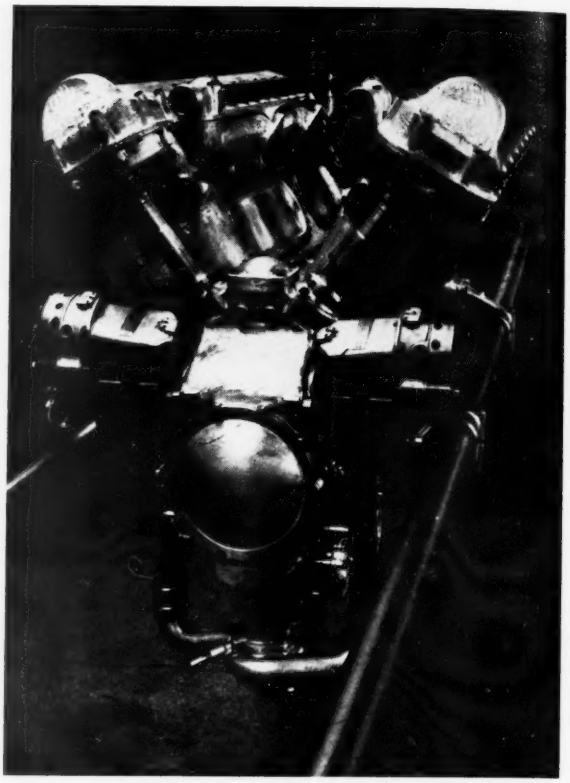


FIGURE 9. First "F" Engine.

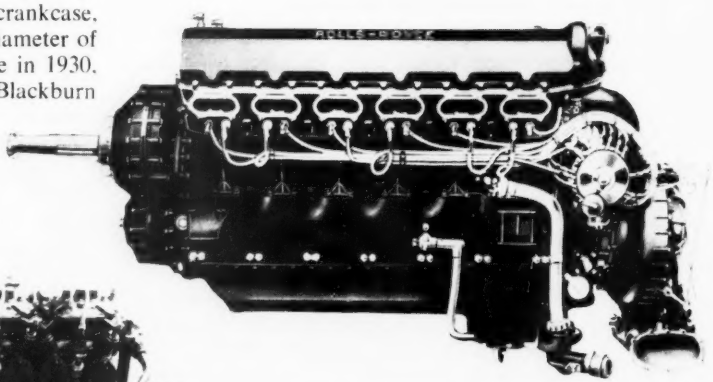


FIGURE 10 (*above*). "H" Engine or "Buzzard."

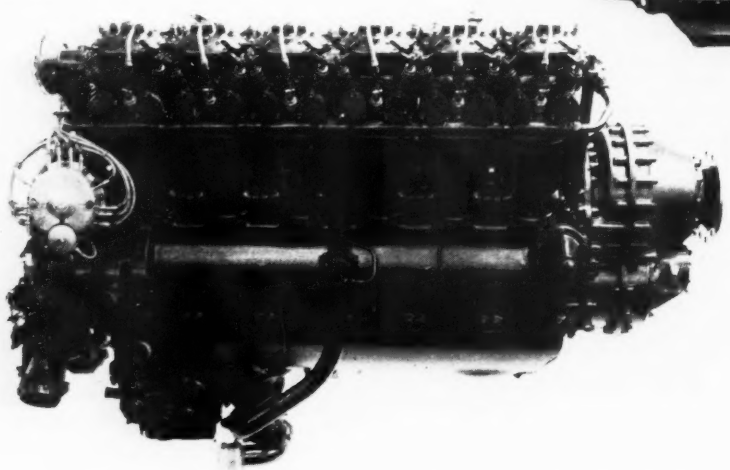


FIGURE 8 (*left*). Condor Series III B.

FIGURE 11. F. H. Royce (*left*), C. L. Jenner (*centre*), E. W. Hives (*right*), under the Mulberry tree.

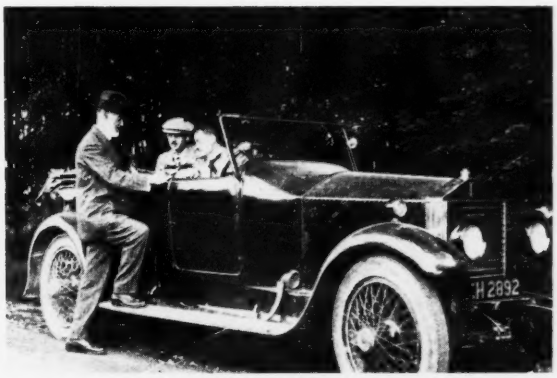


FIGURE 12. F. H. Royce (*left*), C. L. Jenner (*centre*), A. G. Elliott (*right*).

Condor Series V saw the first introduction of a blower, but this engine, like the subsequent Series VI, VII and VIII, never reached production quantities.

In January 1925, a new Eagle was already on the drawing board at West Wittering; apart from having 16 cylinders arranged as an "X" of four banks of cylinders at 90°, it had cast aluminium cylinder blocks, each block comprising four cylinders with dry liners. This engine never got beyond the experimental stage, but it marked a break away from what, for Rolls-Royce, had become a traditional construction.

This design did not proceed beyond the experimental stage.

In July of that same year, the first of what was to become the forerunner of a long and famous breed of engines, was being projected by Royce at Wittering. It was the F.X engine, later to be christened the Kestrel. Although it retained the original Eagle form of 12 cylinders, in 60°V. formation, its novelty lay in the use of two cast light alloy cylinder blocks with wet steel liners, and a totally enclosed valve gear.

The engine of 21·24 litres first ran in March 1926, and made its first public appearance at the Hendon Air Pageant in 1928, replacing an engine of American origin.

Originally a direct drive, and naturally aspirated engine, by the year 1930, and after considerable development, as the F.X1, F.XII and F.XIV, it was available with a spur reduction gear and in a supercharged form. These engines powered the famous Hawker Hart and Fury series of aircraft, and the Fairey Firefly.

In 1931 the engine was renamed the Kestrel, and was to become an achievement of paramount national importance, as the powerplant of the ultimate development of the biplane fighter, the Super Fury, having a top speed of over 250 m.p.h., the fastest aircraft of the day.

Altogether this engine appeared in 16 versions and was used in many types of aircraft, large and small. Starting with aircraft made by the Hawker Company, bearing such famous names as Hart, Demon and Fury, it also powered the Fairey Firefly, the Fairey Hendon night bomber and the Handley Page Heyford.

As the Kestrel XXX, in the Miles Master trainer, it saw service in the Second World War.

Typical of Royce and his team at West Wittering, and at Derby, although heavily charged with the perfecting of a considerable range of engines, they could not desist from planning a new and larger engine embodying their latest knowledge.

So, in 1927, Royce authorised Derby to begin the design of a new engine of 36·7 litres, the Buzzard, in effect a scaled-up version of the Supercharged F.X Engine, the first prototype of which was built by July 1928. The Buzzard was used in the Blackburn Perth Flying Boat, Short Sarafand Flying Boat and the Blackburn M.1/30 T.S.R.

The amazing speed with which these new projects were conceived and designed is a testimony of the skill of Royce, but it was made possible only by a design team built up in Derby by Royce under the guidance of Mr. A. J. Rowledge, who had joined the company at about the end of the War and, by the development team under Mr. Hives. Royce believed in team work. He fostered and maintained it by his powerful control and magnetic personality. Almost weekly visits were made by Hives and Rowledge to West Wittering, to discuss impending designs, and the results of recent tests. When the weather was fine, these conferences took place in the shade of the mulberry tree at the end of the old English lawn at Elmstead.

PART V

The progress in aero-engine design made by Royce in the post-war period, must not overshadow the parallel development which he made in the motor car. When the war broke out in 1914, the Silver Ghost had become accepted as the "Best Car in the World". Great progress had been made by the automobile industry of the U.S.A. during the war. Electricity had come to the motor car in the form of electric lighting and the electric starter.

Immediately after the Armistice, work started at Derby, in the Airship Drawing Office, to install a Hawk

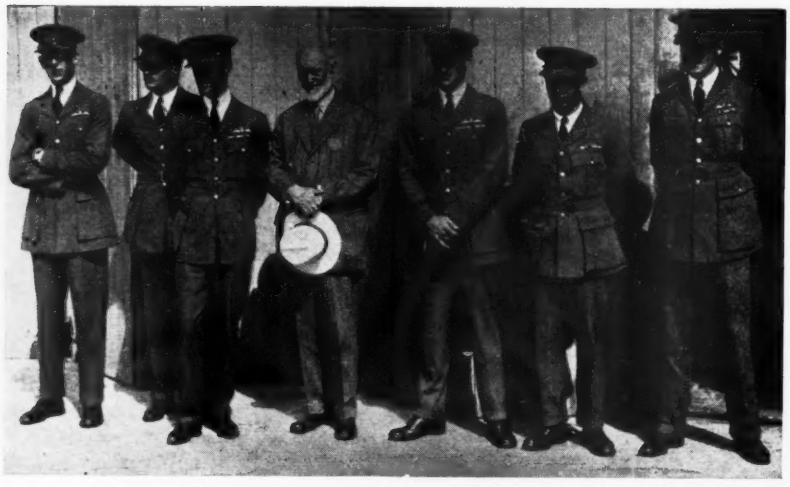


FIGURE 13. F. H. Royce with Schneider Trophy Pilots at Calshot, 1929.

aero-engine in a pre-war experimental chassis, known as the Northcliffe. This car was built, but it became obvious that this engine, even if de-rated, could not, in the time available, be made to give the silence and smoothness which were the requisites of a Rolls-Royce car. Consequently, design work went on at a frantic pace to modernise the Silver Ghost, by obtaining more power from the engine and by adding all the modern features such as electric lighting and starting.

In 1914, so far ahead of its time was this car that it could maintain the great name in 1920 and live on until 1925, when, with only a change of engine, it became the Phantom I. Not until 1929, with the advent of the Phantom II, was seen the last of the Silver Ghost Chassis—a life of 20 glorious years.

In 1919, during the post-war depression, Royce started the design of a smaller car—the 20 h.p. Rolls-Royce. At its inception, it was a Cloverleaf, with an overhead camshaft 6-cylinder engine, but the following year a new overhead valve, push-rod, engine was designed and the chassis was lengthened to take all the normal forms of luxury coachwork.

It was during the pressure of this work that in April 1921, I was invited once again to go to Wittering. A small artist's studio in the village had been rented to house additional designers, under the care of Mr. B. I. Day, who had headed the Derby office. This time I was lucky enough to survive the initiation period and was to stay for twelve years, working on the designs for Rolls-Royce and Bentley cars. This was the culmination of all my hopes of the previous five years. The 20 h.p. Rolls-Royce was launched in 1922 and in 1925 the Silver Ghost was given a new engine with overhead valves, operated by push rods, and the car re-named the Phantom I.

PART VI

The Schneider Trophy Air Race, the Blue Riband of the air, had been won only once by Great Britain since its inception in 1913, until the victory of the Napier Lion-Engined Supermarine S.5, in 1927. The following year, discussions with both Supermarine and the Gloster Company were instituted concerning the possibility of a Rolls-Royce engine being used in machines for the 1929 Event.

It was not until late February 1929 that Air Ministry support for the event was guaranteed, and only then Supermarine accepted Royce's proposal which, owing to the limited time available, was to modify the then existing Buzzard Engine by incorporating a double-sided centrifugal blower and an improved induction system, a higher engine speed and the use of special fuel. By this means it was hoped that 1,500 h.p. could be available. Thus the " R " engine was born.

Royce at West Wittering set to work unceasingly, assisted by Hives and Rowledge at Derby, and by 14th May of that year the first engine had run for 15 minutes, giving 1,575 h.p. at 2,750 r.p.m. By 27th July, an hour's run had been completed, and in August a satisfactory life of one hour 20 minutes had been

FIGURE 14. Schneider Trophy Tea Party 1929, at Elmstead. Reading clockwise from Miss E. Aubin, H. I. F. Evernden, F. H. Royce, A. G. Elliott, B. I. Day, W G. Hardy, R. L. Marmont, C. L. Jenner.

achieved at 1,850 h.p. In less than 12 months the power of this engine had been doubled.

During this period, visitors were frequent at Elmstead and life for Royce became changed for a while. Of retiring disposition as he was, Royce was persuaded to go round to Calshot on several occasions to see the work of preparation for the race and to meet the pilots. Strangely enough one of the turning points of the course for the race was in the village and Royce watched the progress of the race from a haystack on his farm.

Elated as he was with the victory, and the successful culmination of the work of the past few hectic months, his chief emotion was one of relief that no pilot had lost his life in the contest. The stress and strain had taken their toll and he was confined to bed for several days. To celebrate the occasion he invited us later to a tea-party on the lawn under the mulberry tree.

That year several attempts were made on the air speed record with the Supermarine S.6. The last and most successful was on 12th September when Sqdn. Ldr. Orlebar registered an average speed over the course of 357·7 m.p.h.

In the birthday honours of 1930, Royce was created a Baronet.

The decision of the Government not to sponsor the event in 1931 and the timely and generous offer of Lady Houston, left little breathing space for the preparation of the engines and machines.

Finally the S.6 machines were made available by the Government and in the nine months which remained, Royce and his team succeeded, by re-design and intense development, in obtaining a life of one hour for the " R " Engine, giving 2,530 b.h.p. at 3,200 r.p.m The design work had begun only 9 months before the race. Among the many features included in the new design were modified connecting rods, and the use of the new R.R. Alloys and salt-cooled valves.

The development of the " R " engine, which was to win outright for England the Schneider Trophy, will ever remain a classic example of team work by engineers, giving united effort to achieve an ideal, when led by a great captain.

FIGURE 15. S.6. Supermarine Seaplane.

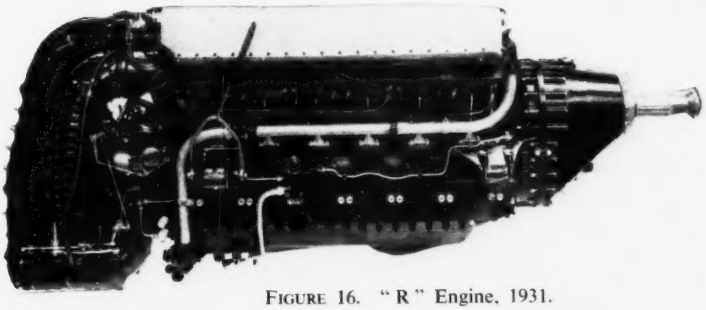


FIGURE 16. " R " Engine, 1931.

That year the S.6.B., piloted by Flt. Lt. Stainforth and fitted with a sprint version of the " R " engine, put the World Air Speed Record up to 407·5 m.p.h.

In tracing the story of Royce and the Schneider Trophy, serious omissions have been made.

Intensive design and development work had been going on during this period on the " F " engine which in 1931 became the Kestrel. Much of the knowledge gained in the development of the " R " engine had been incorporated. This was to extend the development life of the engine for many years to come.

In the autumn of 1931, designs for a new private venture were appearing on the drawing boards at West Wittering. These were for the P.V.G., a modified version of the Kestrel, having the same bore and stroke.

This engine, subsequently christened the Goshawk, appeared in the moderately and fully supercharged form and was used in, among other aircraft, the Hawker High Speed Fury and the Westland Pterodactyl.

In the Motor Car world, Royce had found time to plan and design an entirely new 40/50 h.p. car, the Phantom II, to replace the earlier model, carrying a stage further the epithet which it well deserved, " The Hidden Hand of Power." This car appeared in the autumn of 1929, and soon afterwards followed the Continental Phantom which set a new style in luxury sports cars.

In 1931, the Company acquired Bentley Motors, and the sporting world wondered what Royce would produce to succeed the highly successful 4½, 6½ and 8 litre cars of that breed. He invented the Silent Sports Car, by putting a Rolls-Royce engine in a small light chassis which had been designed and produced but abandoned for policy reasons.

I well remember the January of 1933, when after many projects had been started, but abandoned, the " Old Man " came into " Camacha " and said that he wanted a ¼ scale layout of the chassis and body as well as a small illustration of the car for him to show to the Board of Directors in three days time. From experience I knew that the consequences of suggesting that this was impossible would be fatal. By working two days and two nights without sleep, I produced the drawings.

I took Sir Henry to the station, to put him on the London train, and just before the train pulled out, he said " You must be tired—go home to bed and when

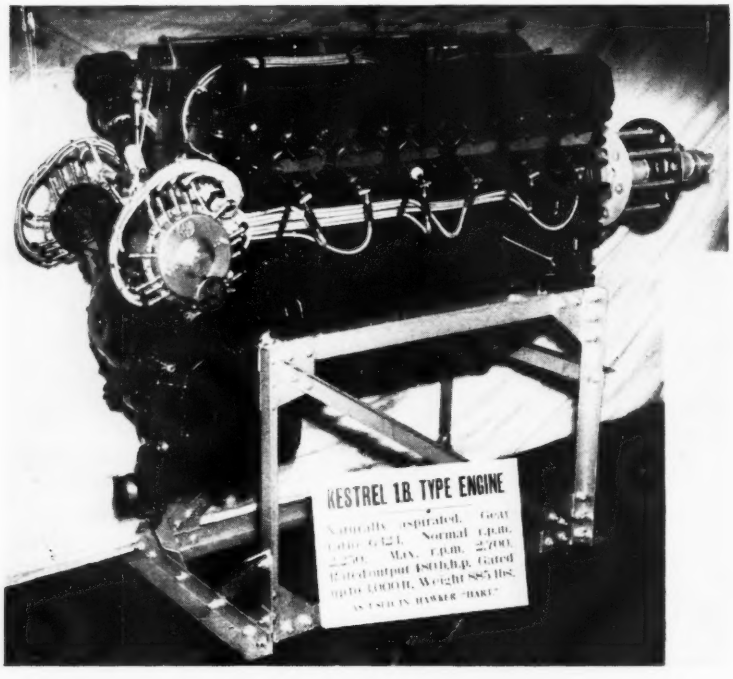


FIGURE 17. Kestrel 1.B.

you have rested, take my car and with your wife, go for a holiday!" This must rank as one of the few occasions when Royce recommended a holiday.

PART VII

Although Sir Henry's health had not been bad, it certainly had not been improving. Often he was confined to bed for a few days. In the better weather, of which West Wittering had its share, he would get up at about lunch time and spend an hour or so with Mr. Elliott and his team at the house. After lunch he would stroll along the shore with his dog Rajah.

On several occasions, visitors to our office in the village told me they had met in the village a tall and stately old gentleman, in panama hat and tweed suit, who, in a soft voice and with a gracious smile, had directed them to Camacha. On his return from his walk he would call at Camacha at about 5.30 p.m., the time when we should have been leaving, and he would stay until quite late in the evening.

Once I set our little old alarm clock to ring at 6 p.m. In surprise, he looked up from the design he was studying, observed that we had no telephone, and then said to Rajah the dog "That's to tell us to go home!" I feared the consequences, but there were none. On one or two evenings later, he did say "We had better go, Rajah, before the bell rings".

Towards the end of 1932, the company realised that in the "R" engine they had a basic design which would give our air force the lead over any other in the world.

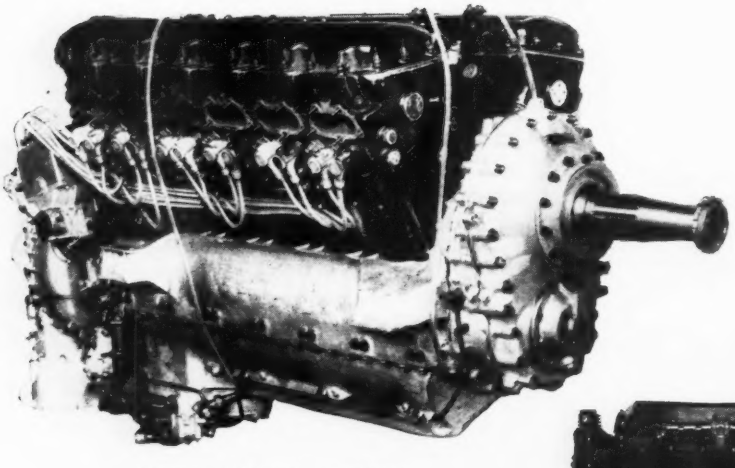


FIGURE 18 (*above*). Goshawk.

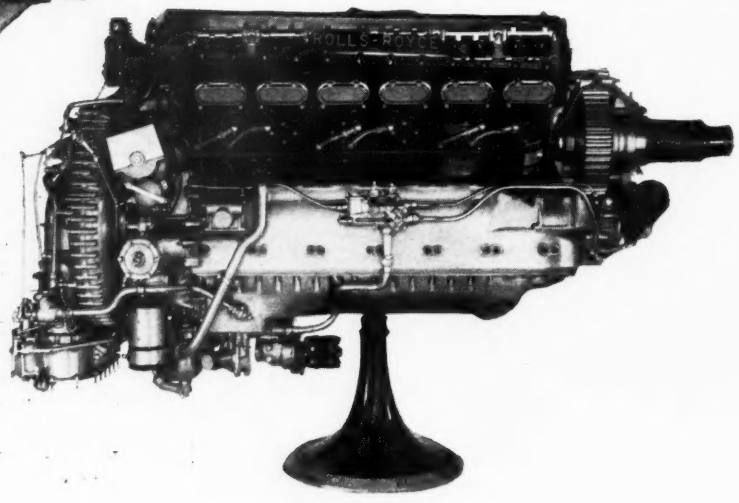


FIGURE 19 (*right*). Merlin II.

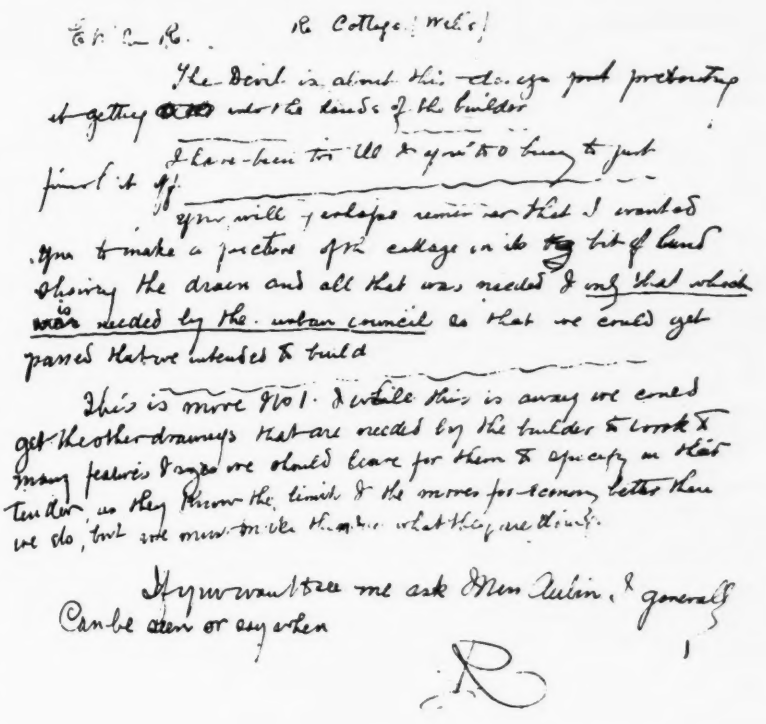


FIGURE 20. Hand Writing of Sir Henry Royce, Bart., April 1933.

Although Government support was not forthcoming, it was decided to design and produce an engine of about 1,000 h.p. embodying all the knowledge already gained. This engine was to be called the P.V.12—P.V. standing for "Private Venture."

Sir Henry's health was fast failing and he could not do more than provide guidance to the team in Derby, now including Mr. Elliott, upon whom the burden of the work fell. This engine was very soon re-named "Merlin" and was to carry on the "Magic of a Name" into the great battles of the Second World War.

Sir Henry's health would not permit him to journey to his villa in the Riviera for the winter that year. Much of the early part of 1933 he spent in bed, but even so he was not inactive mentally. He would give audiences in his room, study current designs and send back to us hand-written instructions.

For some years he had taken an interest in farming and had acquired some 70 acres, which were cultivated under the direction of a local farmer by the name of Balchin. He undertook this work with the same thoroughness and careful attention to detail as he did the aeroplanes and motor cars which he designed. Only when some of his novel ideas produced eminently satisfactory results, to the amazement of his farming neighbours, did they begin to respect this facet of his genius.

He decided to build a farm cottage and while he was confined to his bed, he made several drawings and wrote a detailed specification for the builder, which he showed to me on 13th April. I still have all those sketches with his hand-written notes.

Again working almost night and day, racing against time, I was able to produce plans for submission to the Council before he died on 22nd April at 7 a.m., but too late to receive his signature to the contract.

That cottage, unique in its design, economical in its construction, and an example of correct engineering construction, would have been a fitting memorial to the Great Man.

The greatness of Sir Henry Royce was founded on many things, but above all on his ability to observe accurately, and to reason logically, no matter what the subject. This faculty had been perfected by his early life when he had been compelled to teach himself. He loved solving problems, particularly if they were said to be insoluble. Consequently, he had unlimited patience and was unaware of the passage of time. As a teacher he was superb—except that his rate of deduction was so fast that the student felt breathless in keeping up with him. He was never satisfied with what he had done, and consequently great difficulty was experienced in getting him to release a design for production—a subject which he never understood.

His freshness of mind made him never grow old and, while never a pioneer, he was always striving to make improvements, by logical deduction.

This quality often caused embarrassment to his colleagues on whom the welfare of the Company rested, for he would work with us on an improved escapement for his grandfather clock, or a modified valve gear for his farm tractor, or even on domestic appliances, when other urgent matters awaited his attention.

He had no desire for riches or greatness.

The words Recreation and Sport were not in his vocabulary. Games to him were a futile waste of time, as exercise could be obtained by physical creative work, such as gardening.

Essentially a mechanic, he was suspicious of academic learning, and regarded it as just another tool in the tool box, to be used only as a last resort.

It is fortunate for this country, and indeed the world, that at the right times, he was fortunate enough to meet the right people. Without this good fortune, because he was not a business man, he might possibly have died in obscurity, having spent his days as a first-class mechanic.

Some people wondered as they saw the coffin pass slowly down Elm Lane to the village in the very silent and ancient Rolls-Royce hearse, "What will Rolls-Royce do now the Old Man has gone?" Of the many great achievements of his life, perhaps the greatest of

all was the building of a unique engineering organisation which would enable his work to go on; that body of engineers, dedicated to uphold and to practise his doctrines.

During his lifetime, he had by the eminence of his office in the Company, placed engineering in the foremost position of importance in the Company's policy.

Because those he left behind have built on the foundations which he laid, in spite of the loss of its great founder, the Company has been able to build to even greater heights—all to the glory of Sir Henry Royce.

DISCUSSION

DR. E. S. MOULT: He thanked Mr. Evernden for a wonderful story and a most moving tribute to the memory of Sir Henry Royce. What he had told them was encouragement to all of them and would be a source of inspiration for members of the Society for many years to come. He said inspiring advisedly, because the life of Sir Henry Royce was dedicated to his work and to the perfection of things mechanical. He thought they needed such inspiration today when, despite many of the advantages of training and facilities which were denied to Sir Henry, they frequently got disheartened by their problems and the difficulties besetting them. Things were so much more scientific than they were in Sir Henry's day and if the formula did not give the perfect solution immediately, some of the younger engineers feared the end of the world was near. No formula was better than its assumptions and there still remained a high proportion of engineering art and of sound judgment in their activities. It was too much to expect to see all the light all the time and they needed the inspiration of Sir Henry and others like him to give them that judgment and a little technical doggedness when things did not go so well.

There was to be no discussion in the normal sense but he would call on one or two people to add to this tribute to Sir Henry and then, if time permitted, anyone else with either personal knowledge or acquaintance with his work might wish to add their tribute as well.

LT.-COL. L. F. R. FELL (Public Relations Manager, Rolls-Royce, *Fellow*): He had listened to Mr. Evernden's admirable lecture with genuine pleasure as it brought back many happy memories of visits to Sir Henry Royce's home at West Wittering during the last 10 years of his life.

As one of those who knew him well, he would like to congratulate Mr. Evernden on the accuracy of his presentation of Royce, the man.

In retrospect he thought that what impressed him most about R was his sincerity. In the dictionary the first meaning of the word "sincerity" was "free from pretence". Royce could not tolerate insincerity or pretensiousness in any form. His home was very simple but everything in it was the best of its kind. On the other hand he well remembered his condemnation of someone who had so far degraded himself as to purchase some small tools from the 3d. or 6d. stores of those days. Such tools could only *look* good but they could not *be* good at the price.

He thought it was his sincerity which endeared him to children and caused him to be interested in them as he was not a sentimental man. Children said what they thought and he liked it that way. He would frequently turn from the "grown ups" who might be trying to impress him to talk to a child who was just being himself or herself.

His approach to engineering work was entirely governed by his insistence on sincerity. To Royce nothing in engineering was truly perfect. You did your very best in design and development but you had to "go to press" sometime to keep in business.

He was often described as a "perfectionist". Again referring to the dictionary he found that a "perfectionist" was "one who holds that perfection *may* be obtained". As an engineer, therefore, Royce was no perfectionist.

Those who were now charged with the duty of carrying on Royce's work did not need to be perfectionists so long as Royce's tradition of sincerity was maintained.

AIR COMMODORE F. R. BANKS (The Bristol Aeroplane Co. Ltd., *Fellow*): He met Sir Henry Royce three times—first when he was a boy with his father, who knew the Hon. C. S. Rolls very well; and if as was said Royce was kind to children he could only say that on that first visit to the shops Royce paid more attention to him than to his father or to C. S. Rolls, in explaining things. He saw Royce twice more, once at West Wittering and once when he made one of his visits to the Schneider Trophy team at Calshot.

He thought any of those who had been trained as mechanical engineers could only look up to Royce as a sort of a god of mechanisms; and one of the nicest pieces of simple mechanism he had ever seen and tried was the gear lever in the gate shift of the Silver Ghost. With Silver Ghosts of all ages, one could flick the lever into any gear with a finger. As a mechanic and a mechanism perfectionist he thought Royce had few equals.

What Royce left to this Country was a firm which would always live in their minds as representative of engineering art at its highest. The strength of any firm was in the team that had been built up and who could carry on after the founder—to give continuity.

He had heard one or two stories about Royce, but whether they were true or not he was unable to say. He always remembered the one about choosing a new cook, when the first thing Royce would ask a candidate was if she could boil a potato properly. One prospective cook was so irritated that she left immediately—"of course she could boil potatoes"! Eventually, Royce got the more willing ones into the kitchen to show him if they could boil a potato to his liking. Royce was

said to carry his perfectionism to the fire grates in West Wittering, and he got his coal from Derbyshire—he believed Derby Brights—and his coke from Waddon (near Croydon); and woe betide anyone who made those fires smoke. They all had to glow, with complete combustion.

Another tale was that Royce went out one day and found a hinge of the garden gate needed attention—it lacked a screw or wanted one tightened. He started off to do the job, but when he eventually found the screwdriver he was so disgusted with its design that he got on with making a new one. He had not heard whether the screw ever got put in the gate!

DONALD EYRE (Senior Designer, P.A. to Chief Scientist, Rolls-Royce, *Associate*): Mr. Evernden had related the main points of Sir Henry's life and of the formation of Rolls-Royce Limited, in addition to giving a detailed and most interesting history of the Company's products created under the guidance of Sir Henry Royce. A lecture given in memory of so great an engineering genius must include a step-by-step account of his brain, but Sir Henry's colourful personality, his wit, his eccentricities and his frugality born of his early hardships and poverty, would need many pages in order to paint a true and complete word picture of Sir Henry the man.

For a few years, from 1928 until just before his death in 1933, he had the privilege of designing for Sir Henry Royce; working not only at his home "Elmstead" under the superb guidance of Mr. A. G. Elliott, but also, for half a winter, at his villa "Mimosa" in the South of France when he was the only designer with Sir Henry.

He had taken the photograph which Mr. Evernden included in his paper, showing the tea party on the lawn at Elmstead in celebration of the Schneider Trophy Victory, because this was one of the very rare occasions when Sir Henry permitted any valuable time to be devoted to a get-together and he decided to put his camera in his pocket and to obtain Sir Henry's permission at the end of the meal, to photograph the party; he readily agreed and removed his sun hat.

In addition to Sir Henry's interest in cars, aero-engines, Royce Cranes Limited and farming, he also, when time permitted, studied art and during the winter 1931/2 at Le Canadel, although ill and 68 years of age, produced one or two quite good water colours.

In support of Mr. Evernden's remarks that Sir Henry worked during the morning, rested for a few hours after lunch and then worked until late in the evening, he had very good reason to remember this sequence. Sir Henry knew that he made a hobby of pictorial art and on arriving at Le Canadel, asked if he had brought his easel and sketching equipment and then told him to work during the morning and go sketching during the afternoon when the light was good. He thought this permission to indulge in afternoon sketching was very unusual for a man so intent on engineering work, but then Sir Henry added that he was to return to the drawing office and work "until my conscience was clear". This, of course, meant working hard with him until about 10.0 p.m. each evening.

Even at "Elmstead", Charlie Jenner and he would find each morning on arriving at their drawing boards, that their design schemes had received close scrutiny by Sir Henry during the previous evening; each drawing was literally covered with scribbled notes of criticism and when Sir Henry next visited their boards, he would expect to find the whole design corrected in line with his requirements.

He might add that they were not only in full agreement with these modifications, but that they recognised the brilliant mind behind them, and learned more from each criticism than years of their own efforts would have taught them.

This was designing at its best; aiming solely at absolute perfection regardless of effort and without aiming at completion to a specified date, in fact, if Sir Henry could find a way to improve a design which was nearing completion after weeks of hard work, the whole scheme would be altered to incorporate the improvement.

MAJOR G. P. BULMAN (Ministry of Supply, *Fellow*): His was the happy and easy task to propose formally the vote of thanks to Mr. Evernden, to whom they had listened with fascination; a wonderful picture of a great man drawn by an artist with a loving pencil. Mr. Evernden had obviously sat at the feet of the great *maestro* those sixteen years, whereas only few of them present had had the privilege of meeting Royce at all. In his tribute Mr. Evernden had blended skilfully the picture of the man and the background of his achievements.

This was an historic occasion and he would like to fill in one or two little footnotes of history. First the Kestrel. Dick Fairey (Sir Richard, to whose memory they had earlier paid tribute) bought the Curtiss D 12 to put into his Fairey Fox because he was then dissatisfied with what he thought he could find from British designers. It was that "D 12 in the Fairey Fox" which really put the spurs into Rolls-Royce and gave them a super boost, without which he thought the Kestrel would have taken longer, and perhaps not have come out quite as well as it did. So, poor Dick Fairey having bought the Curtiss D licence hoping to go into engine manufacture, got an order for only one Squadron of Foxes for the Royal Air Force, whereas Rolls-Royce established the Kestrel in production, and that of course led on to further things.

Then the Schneider. Things did not go quite so easily in the great decision to choose the Rolls engine as Mr. Evernden suggested. He himself had but recently taken over Headship of the engine development side in the Air Ministry, in 1928, and Reg Mitchell and he—pretty young then—had most agonising discussions as to whether Mitchell should continue to back the Lion with which he had won in 1927, or risk everything on a comparatively unknown horse based on the Rolls-Royce Buzzard, which had not so far been conspicuously successful. It was contrary to his own

feeling, to gamble over far, but Reg Mitchell and he jointly decided that they would back, not so much the Buzzard, but Henry Royce, Rowledge, Elliott and Hives. They put their money on those men. But, a certain high official in the Company, on the administration side (*not* Sidgreaves) was not at all anxious to associate Rolls-Royce with racing. He said that if they failed, it would be a frightful blow to their prestige. In fact, he was very resistent to the idea. Claude Johnson by then had died. He remembered Claude Johnson, a man of commanding presence and amazing charm; he had always regarded him as a prototype of an Ambassador. But he had gone and the one that came in his place, as he said, was reluctant. So Air Marshal Sir John Higgins who was then the Air Member in charge of Research and Development in the Air Ministry, and he, met the firm's representative who again pleaded not to be forced into this project. Being himself intensely worked up, he gave, quite unconsciously he was afraid, utterance to a very short word, fairly common in purely masculine society. Old "Josh" Higgins heard this, looked at him, and then said 'Mr. —, I order your firm to proceed with this Rolls engine for the Schneider Trophy", and that was that.

One small footnote about the Merlin. Mr. Evernden said that it began without Air Ministry support. Well, the support was offered but it was not accepted. The firm prepared to go ahead with it as a private venture, no doubt because they thought they would be freer to deal with ultimate royalties and so on, but it was not long before they came along and said "We will accept your offer of a contract", and got it. The P.V. 12, as Mr. Rubbra would confirm, began life "upside down," with the cylinders inverted but the aircraft designers, he thought rather unfortunately, were rather conservative then, and they did not like it "upside down" and so it was turned right side up, whereas the Germans in the Junkers and the Daimler, later, in the war, produced their engines inverted.

Henry Royce himself. He had met him only a few times. The first occasion was under the mulberry tree at Wittering in the spring of 1929 when Rg. and E. and Hs. had taken down the prototype pieces of the first Schneider engine and laid it out on the lawn and they spent all day looking at and discussing these bits and pieces. He remembered Sir Henry, gazing at them, would say "Rg. that's very clever, a beautiful job. But I think perhaps if we just did that, it might be better . . . Well, now this thing, I don't think that's very good, you know. Shouldn't we do that to it?" And so in the course of the day there were quite a lot of modifications made and they all came out right. He was a man of such extraordinary simplicity. So often Sir Henry would cut short some cackling argument and say "Gentlemen, all that matters is 'what's the job want'". That, he thought was rather the key-note of his life. He hated ill treatment of machinery much as they all disliked cruelty to children and animals. The tale went that somebody drove down to see him at Wittering in a rather dilapidated and very ill-kept motor car and Sir Henry was at the gate to meet him. He looked at the car, said nothing to the man in it, pottered off to a little shed, came back with a little tin of oil and a brush, got down on his back under the car and oiled the springs of the car, went away, washed himself, came back and said "Oh, how are you, so nice to see you. I just couldn't leave your car like that".

Very few people he thought realised the humbleness of the origin of Royce; that in fact he began by selling newspapers. The striking thing was that despite the hardship of his upbringing, the lack of any "welfare state" in those days, it never embittered him at all. He could be ruthless in sacking a man at sight, probably take him back next day, but towards the world at large and humanity in general he was kindly, understanding, and tolerant. His early poverty, his vicissitudes, his physical handicaps, never soured him; in such contrast to so many people who having perhaps a less hard time in their youth, were bitter and venomous and vinegary for the rest of their lives.

And so it was a great privilege for all who met the great *maestro*. All of them must surely have found him an element of inspiration in their own development, and they thanked Mr. Evernden for bringing out, and reminding those who knew him, and telling those who were not privileged to meet the great man, something of his great character. So he most sincerely and happily proposed a formal vote of thanks to the lecturer.

DR. E. S. MOULT: He thanked Major Bulman for a moving tribute. When they came to this hall they all knew that Sir Henry Royce was a very great man and what they had heard, thanks very much to Mr. Evernden, had confirmed that view, strengthened it tremendously and, as he had said earlier, it would be a great inspiration for many years to come.

High Speed Test Flying

by

Lt.-Colonel CHARLES E. YEAGER, U.S.A.F.

The 991st Lecture to be given before the Society, " High Speed Test Flying " by Lt.-Colonel Charles E. Yeager, U.S.A.F., was given at the Institution of Civil Engineers, Great George Street, London, S.W.1, on 19th April 1956. Mr. N. E. Rowe, C.B.E., B.Sc., F.I.A.S., F.R.Ae.S., President of the Society, presided for the first part of the meeting and Sir Sydney Camm, C.B.E., F.R.Ae.S., Past President, for the second part.

Opening the meeting Mr. Rowe regretted that he was unable to stay for the Discussion but he had particularly wanted to hear Colonel Yeager who was a world figure in the subject on which he was going to address them. This was the concluding lecture of the normal session this year (apart from the Wilbur Wright Lecture) and he felt that they could not possibly have anything better than the occasion which they were going to enjoy that evening.

The lecturer had had a very full life although he was still young and he would touch on a few of the high spots.

Colonel Yeager joined the Army Air Corps as a private and became an aircraft mechanic—so he knew something about the works before he went into the office—and he received his commission as a Second Lieutenant in 1942. He had a distinguished War career and he finished as a group leader. He was an escapist—he was shot down on his twelfth mission, smuggled by the French Underground into Spain, was put into prison; they forgot to take away his escaping kit, he sawed his way out by a highly tempered saw and got back to England and continued with the job. For his work in the Second World War he was awarded many distinctions including the Silver Star with one oak leaf cluster, the Distinguished Flying Cross with oak leaf cluster, the Bronze Star, the Air Medal with seven oak leaf clusters and the Purple Heart. Colonel Yeager was transferred to Wright Paterson Field and in January 1950 he was re-assigned to Air Research Development Command, Flight Test Center, at Edwards Air Force Base, which some of them visited at Muroc last year when they visited America.

Colonel Yeager's first great world-shattering achievement was to pass through the sonic barrier, October 1947. This was done on the Bell X-1 which was taken into flight on the B-29 and did its great flying after reaching high altitude. He actually took off in this aircraft under its own power using rockets and did a very astonishing climb at supersonic speeds, achieving a rate climb of 13,000 ft./min. He thought that in itself was an astonishing feat.

For these records, Colonel Yeager was presented with the Mackay Trophy by the Chief of Staff of the United States Air Force, the Collier Trophy by the President of the United States and he was voted the " Airman of the Year " for 1951 by the Civil Air Patrol Cadets of fourteen nations.

In December 1953, he piloted the Bell X-1A at 1,650 miles per hour and in December 1954 President Eisenhower awarded Colonel Yeager the Harmon Trophy at the White House. The Junior Chamber of Commerce of the United States named him one of the ten outstanding young men of 1954. Since February 1955 he had been with the 50th Fighter Bomber Wing in Germany and it was said, and he was sure it was absolutely true, that he was glad to be back working with a tactical organisation because he enjoyed the team spirit.

This was a brief record of tremendous achievement over a comparatively short flying life.

(The following is a verbatim report of Colonel Yeager's Lecture and the Discussion, which were recorded.)

I AM VERY HONOURED here tonight to see such a capacity. When I received the invitation from the Royal Aeronautical Society to give a lecture in front of such a distinguished group I had a sort of funny feeling. Engineers always scare me and, actually, there are people in the audience who are as qualified as I am, and maybe more so, to talk about my subject. So it is just like talking to a snake charmer about fish worms.

Peter Twiss and I had quite a conversation prior to coming here tonight. Actually we met over at The Hague at the Air Show that they had on the 50th Anniversary of Flight, and I was telling him that this has been a very trying day from having so many interviews with the Press that I was afraid I was just bled out. That's all there was to it. It is a good thing that I have told the speech before that I am about to give tonight, because I have told it so many times that I am beginning to believe it myself.

The subject suggested was my experience with experimental or high speed flying. My association with that type of flying I thought would be of interest to you if I discussed some of the aeroplanes that we did it with.

In World War II when Spitfires and Mustangs and Messerschmitt 109s and other aeroplanes of that category were quite common, we were all aware of the troubles that these particular aeroplanes got into when starting to dive. When getting up to around 80 per cent of the speed of sound, the aeroplane starts shaking, buffeting we call it; some of them lost ailerons and tails and it proved to be fatal to some of the pilots. It was quite obvious to all people who have an engineering mind that something just was not quite right, especially in the speed range they were flying in those days.

I will try to cover one aeroplane that was developed, or was conceived, out of this old type of thinking. I refer to the Bell X-1. The engineers and scientists of

Courtesy of The Aeroplane.

Lt.-Col. Charles E. Yeager, U.S.A. (*centre*) with (*left*) Mr. Peter Twiss, Fairey Aviation Co. Ltd. Test Pilot, and (*right*) Sqn. Ldr. Neville Duke, at that time Chief Test Pilot, Hawker Aircraft Ltd. This photograph was taken at the Society an hour or two before Colonel Yeager's Lecture.

the National Advisory Committee for Aeronautics, since aeroplanes were having so much trouble in this speed range which was approaching the speed of sound, thought it best that we build an aeroplane that would fly in this region to find out just exactly what was happening. So in 1943 the idea was conceived to design and build an aeroplane that would actually fly at speeds of a Mach number of one, or a little faster, to see what type of stresses and forces caused aeroplanes to buffet and shake and lose their tail surfaces.

The aeroplane went the way of all aeroplanes, drawing up on paper, trying, and improving and finally it came out as a piece of hardware in 1946 in flyable condition. Now this aeroplane, sent to us to fly in a region that very little was known about, was built to take a stress of 18 *g*'s positive and about 10 *g*'s negative. That is, compared with the normal production fighter that we know today—the Hawker Hunter or the Sabre—the F-100 is designed to withstand 7·5 *g*'s before it starts to bend and it breaks a little bit above that. It was decided that this aeroplane, the X-1, since we had not jet engines that would drive an aeroplane as fast as we wanted this aeroplane to go, should be powered with rocket power. The most common and the safest fuels were liquid oxygen and alcohol, so that was the type of propulsive fuels that we would use.

The X-1 was finished, they installed a motor and prior to the powered flights they thought maybe we had better drop this aeroplane from a B-29, because it only carried 288 gallons of liquid oxygen and 300 gallons of alcohol and this gave us enough fuel for only 2½ minutes of full power. If we took it off the ground, by the time we got up to altitude with it we wouldn't have enough fuel left to do any work with. So they modified a B-29 by cutting the bomb bay out and fixed a plain B-7 bomb shackle in the bottom of the B-29. They put some hooks in the top of the X-1 and hoisted it up under the B-29, then decided to drag it upstairs and kick it out.

The aircraft, after being completed as any conventional type aeroplane would, had no Rotary engines in it or any source of power to run a hydraulic pump or run big pumps to force the fuel back to the motor. We incorporated in the X-1 a pneumatic system which raised and lowered the gear, worked the flaps, pressurised the cockpit and ran the gyros for flight instruments, the same as electrical power or hydraulic power would in a normal aeroplane. The aeroplane so designed was made up of just a fuselage, two straight wings, horizontal stabilisers and elevators and vertical stabiliser and rudder. I think that is the basic group of any aeroplane. The aeroplane had no boosted controls, the horizontal tail was not flyable. You could change the angle of incidence of course by a little air motor that ran a jack screw that ran it up and down. It was a very crude way but it was effective and that was all we were looking for and in the forward part of the fuselage was a large sphere-tank that held 288 gallons of liquid oxygen; the pilot leaned against it when he was sitting there—it was very cooling to his perspiring back you might say.

Aft of the wing we had the same shape sphere which held 300 gallons of a mixture of 5 parts alcohol to one part water and this was all we carried aboard. We had a manifold system which we pressurised up to 5,000 lb. sq. in. of water-free gases—nitrogen. This nitrogen we bled through regulators and it was used to pressurise the liquid oxygen tank, pressurise the fuel tank and force the fuel and Lox into the motor through these large pipes at the rate it was required. We also reduced the gas down to a lower pressure to raise the gear, lower the gear and, as I said before, we actually took the nitrogen gas, ran it through another dome regulator, across our flight indicator and needle and ball to run the gyros and we could actually vent the gas into the cockpit to pressurise the cockpit with, or vent it overboard when we did not want to pressurise the cockpit. It is a relatively simple aeroplane.

The aeroplane made its first twenty flights with a Bell test pilot aboard. When a Company back home builds an aircraft they have to prove that the aeroplane is airworthy in the first part of the contract. In the next part of the contract it calls for taking the aeroplane up to a certain speed and altitude. It just so happened at this point the Air Force stepped in, took the aeroplane from Bell and gave it to the Air Force Flight Test Laboratory at Wright Paterson Air Force Base and being a small aeroplane resembling a fighter, this project was turned over to the Fighter Test Section. I happened to be a pilot assigned to the Fighter Test Section and we all drew straws to see who would get the project, and I came out on the short end, in more ways than one.

To get back to the aeroplane, when we took it over it was quite new to me. I had a little bit of jet time in F-84s and F-80 Shooting Stars and had quite a bit of Mustang time, Spitfire time and so on. It was quite a machine in my estimation. We went out to Edwards where we had the large dry lake bed which at the time was seven miles long and five miles wide, which we figured we could hit on any dead stick landing we had

to make. The aeroplane, the little X-1, was backed down into a pit. I had to learn all of the systems. I practically could name who made what rivet, where. In fact it is very important when you are doing flying in research aeroplanes like that that you know your job. A lot of people are not with us any more because of a little bit of haste when they do that sort of work.

The aeroplane was backed into a pit, the B-29 was pulled over it and they hoisted the X-1 up into the B-29. They pulled it up between the loading pits, filled the aft tank full of alcohol and water and the fore tank full of liquid oxygen and then pressurised the manifold up to 5,000 lb.

The way we got such high pressures is a matter of interest. Since we had no mechanical pumps that would give us that high a pressure, we took liquid nitrogen and ran it through an evaporator by heating it, the expansion of course turning the liquid air to gas. We got tremendously high pressures that bled into our manifold and got up to 5,000 lb. and then we shut it off and vented everything. Then we backed the B-29 out. All of these so-called bomber pilots would get into the cockpit of the B-29; and they would drag the X-1 pilot up to the aeroplane and tie you up to the cockpit of the B-29.

On none of our take-offs with the X-1 under the B-29 did we take off with the pilot in the X-1 cockpit, because the climbing speed of the B-29 is in the order of 180 m.p.h.; the stalling speed of the X-1 fully loaded, which it was at that time, was 240 m.p.h. so if you had an inadvertent failure of the bomb shackle or had a fire in the B-29 and wanted to get rid of the X-1 you would probably lose the X-1 pilot too because he would not be high enough to recover from the resulting stall and spin that he would be in.

So at 7,000 ft. above the ground these two big strong men would pull the X-1 pilot back to the cockpit. You would climb down on a ladder which they would lower into the slipstream. You had your parachute on of course. You would slide into the cockpit of the X-1 and get all squared around, they would slide the door down and you would hook it on from the inside and then you would get your helmet on and get all connected up with your oxygen and radio and check in with the B-29 pilot. All this would take a matter of three to four minutes and the bomber would get on up to about 10,000 ft. Then you would start around the cockpit, setting up all your domes, loading various stages, pressurising your tanks and setting the aeroplane up for the actual flight. All of this would take in the order of 10 to 15 minutes; by that time the B-29 would have climbed up to about 25,000 ft.

On the initial flight of the X-1 that I made in August 1947, we flew the aeroplane without liquid oxygen or alcohol in it; it was completely empty: we just took it up and dropped it just to familiarise the pilot with the landing characteristics and stalling characteristics and the type of pattern you had to set up to land, because it was a dead-stick landing. Your landing speed was in the order of 180 to 200 m.p.h. It was a little critical not to over-shoot or under-shoot, but we had a very long runway to aim at so fortunately we never did over-shoot or under-shoot.

The Bell X-1.

The first drop was quite an experience for me. You are sitting there; it is quite dark, and the bomber pilot starts counting down. He says: "I'll give you a five minute warning here and you can set up all of your knobs the way they are supposed to be set up and set in and get a death grip on the stick." He gives you about a minute warning and then he starts counting down at 5 seconds and he says 5 seconds, 4, 3, 2, 1, drop, and about a minute later the co-pilot finally releases you. As with all bomber crews I think he sits there asleep until the pilot nudges him and says: "You were supposed to drop him." Anyway when you fall out, it comes out with a snap, and the bright sunlight usually blinds you quite severely for a matter of two or three seconds until you become acclimatised to the light. On the first flight of course it was just the same as a glider. We stalled the aeroplane, felt it out, became accustomed to it and by that time it was time to land, to set up a pattern and come on in and land. Very nice aeroplane; considering it had no boosted controls or flying tail on it, it reacted very well.

I had three glide flights like that to become familiar with the landing and handling characteristics of the aeroplane. And then we filled it full with lox and fuel. I will cover the motor here a little bit. The motor, built by Reaction Motors Inc., consisted of four rocket tubes in the back, all tied together. You had four switches in the cockpit that you could turn on and turn off, start and stop a tube as many times as you wanted to, or until you ran out of fuel of course. You could turn on any combination you wanted to, and could turn on 1, 2, 3 or 3, 2, 1, or vice versa, set up any amount of power you wanted in increments of 25 per cent. The little motor put out 6,000 lb. of thrust which, you know, being a rocket motor is 6,000 lb. of thrust regardless of what altitude you go to, that is give or take a few

pounds. Each tube therefore put out around 1,500 lb. of thrust.

My first powered flight, I wanted to feel out the engine. We climbed away as normally as you do prior to the drop, they drop you out and you turn on one chamber and you get a kick in the rear and since your thrust is instantaneous there is no build up. I tried out all four chambers by turning one chamber on and letting it run a few seconds and turning it off. Then I turned on three chambers, climbed up to 40,000 ft., accelerated up to 0·87 Mach number, or 87 per cent of the speed of sound; shut everything off, jettisoned the remainder of the liquid oxygen and fuel, glided on down and landed and crossed myself a couple of times.

After we checked out the data and saw that it worked good and the aeroplane and its propulsion system checked out O.K., we had our programme laid out. We took small steps, increased our speed in very small increments, analysed our data and set up the next flight plan of exactly what we wanted to do. Instrumentation comes up here; how do we record all this stuff? Do we believe all the pilot tells us, or do we takes pictures of the photo-panel? To cover a little bit about the instrumentation in the X-1 as it was back in those days, we had a camera mounted over the pilot's shoulder which started running at drop and ran until you landed. Besides the camera, we had recording instruments in the back which were manometers which picked up pressure points on, say, one or two chords of the wing, one or two chords of the horizontal stabiliser. It also recorded aileron position and forces, elevator position and forces, all of those things which are interesting to know about an aeroplane flying in this region, and it was very clear. Besides that we carried either a 15 or 20-channel telemetering device which transmitted all of this data to the ground. This data was received on the ground even though you did not bring the aeroplane back. They knew exactly what happened to you and they have all this stuff recorded on the ground prior to your arrival so they can sit there and tell you exactly what you were doing.

On the first flight as I said, we went up to around 0·867 Mach number; came down and landed; looked at all our data and instrumentation and it all checked out good so we were ready to start on our programme. That took us exactly six flights. On the second flight we took the aeroplane up to about 0·89 Mach number and we began to run into a little bit of buffeting, the same as occurred with the old Mustangs or Spits or other aeroplanes at about 0·8 Mach. You have got to remember that the X-1 had a relatively thin wing, or what was relatively thin in those days, but not in today's aeroplanes as we know them. The aeroplane had an 8 per cent wing on it and it was straight. So that at 88 per cent of the speed of sound the aeroplane began shaking so that a wing drop occurred, which took a one-third aileron to hold the wing up. We came down and looked at all of our data, which showed us our manometer pressure points picked up on the wing. A shock wave was forming at the thickest part of the wing and was starting to move back, and behind the shock wave, as you know, you have turbulent air. This shock wave also killed off a little more lift on one wing than it did on the other one, so you would get a slight wing drop due to the non-perfect contours. It is almost impossible to make one wing a perfect replica of the other one.

After coming down, we looked over our data which showed the aeroplane was having no tendency to pitch up or pitch down, it was going the way it was headed, and it was not requiring any change in the elevator position to maintain straight and level flight. At the end of this run when we would get up to, say, 0·88 Mach number, we rolled the aeroplane over and increased the lift coefficient at that Mach number. Now a lot of people say, why do you pull g's at a maximum Mach number at speeds like that, it may be dangerous. Actually it is a pretty well accepted fact that an aeroplane flying straight and level pulling one g if it is buffeting and has a slight pitch up or trim change, if you increase the lift coefficient and pull say, two or three g's, then you are more or less duplicating the effects of the Mach number that will occur at a higher Mach number only pulling one g. That is what I was told. It is pretty difficult to explain. I have memorised it myself. But actually that is what we would do at the end of our run—pull a few g's and that would give us an indication on our data that we produced after we came back and would show that the aeroplane would possibly pitch up or pitch down at a higher Mach number straight and level.

On the third flight we took the aeroplane up to about 91 or 92 per cent of the speed of sound. We ran into a little bit of heavier buffeting and we got a little harder wing drop and we took a little more aileron to hold it up and as we pulled back on the stick at the end of the run everything was normal. You shut off the power, the aeroplane starts slowing down; you jettison your fuel and come on home and look at the data again. All this took many days. Flying such an aeroplane is not an everyday occurrence. It is a research aeroplane and if you do not bring back data then you have wasted all the effort you have put into it, so every little thing has to work; preparing our instrumentation, checking it out, making sure that it does work prior to each flight, takes many, many man hours and a lot of people.

On about the fourth flight we took the aeroplane up to 0·94 Mach number, 94 per cent of the speed of sound. At this speed I laid the aeroplane over and pulled back on the control column and the aeroplane did not turn, it went the way it was headed so I shut everything off and came down and had a heart to heart talk to the engineers. We looked at all of our data and it showed that the shock wave that had formed on the horizontal stabilisers the same as on the wing had moved back and attached itself to the trailing edge of the stabiliser just in front of where the elevator was hinged, so all the long-hairs got together and talked and talked and finally they came out with the next programme. We would go up; instead of turning with the elevator, the flippers on the aeroplane, we would change the angle of incidence on the horizontal stabiliser, or change the whole tailplane and make the aeroplane

turn, starting at 0·86 Mach number where our elevators were very effective.

We went up to 0·86 and I changed the angle of incidence on the horizontal stabiliser, turned it down about a quarter of a degree and the aeroplane pulled two *g*'s without moving the elevator. I cranked it back and increased my speed on up to about 0·9 Mach number, changed the angle of incidence on the horizontal stabiliser and got two *g*'s that time. Then I went on up to 0·94 where I had lost my elevator control, changed the angle of incidence one quarter of a degree and got two *g*'s acceleration; the aeroplane turned, which showed us that although we were losing our elevator effectiveness we could still fly the aeroplane with the horizontal stabiliser if it had a tendency to pitch up or pitch down and that little trick you might say is the big reason that practically all of our modern day fighters consist of a flying tail, because above 0·92 or 0·93 Mach number you cannot get any *g* whatsoever. I would not say any *g*, but you cannot get the full amount of *g* the aeroplane is designed to take without having a flying tail on it, because your elevator has lost practically the majority of its effectiveness.

After that it was just a matter of a couple of flights, the buffeting got very heavy and we did get a little bit of a pitch up. On trim change we changed the angle of incidence on the horizontal stabiliser to keep the nose down and we kicked it on up on the sixth flight to about 1·04 Mach number. Came down and looked all over the data. Actually we got a jump on the Mach meter from about 0·96 to about 1·04. Now the reason for this jump was the bow wave in front of the aeroplane, or shock wave, which was forming in front of it. We had our Pitot tube right on the nose of the aircraft and the bow wave or shock wave moved back across the static pick-ups. As you know a shock wave, or sound wave, behind it you have higher pressures than you do in front, also lower velocities and as this bow wave moves back across—this is for those technically-minded people, not for the layman—the bow wave moves back across the static holes, the static pressure increases as the bow wave approaches, the impact pressure stays the same, so you get the same reading as you would with the same indicated air speed at a lower altitude, so you have an erroneous reading there. As your bow wave passes across then your reading becomes true and it will jump up above a Mach number of 1.

We made a total of some 80 flights on the X-1. We had a lot of fires in the rear end of it but fortunately it did not blow up on us, and we lost a lot of pieces off it, but fortunately they made some new ones. The aeroplane itself, being the first aeroplane ever to fly in that region and bring back data—that was a very important step in our Air Force as far as research and development is concerned. All of our data was brought back from these 80 or so flights, under every condition that you can imagine. We completely exhausted the aeroplane's capabilities—we took it as fast as it would go, as high as it would go; pulled as many *g*'s as it would pull under all these various speed ranges and altitude ranges. All of that data was reduced and presented to all our aircraft companies, such as Lockheed, North American, Convair. All of them. And that data was given to the engineers who are designing aeroplanes which take about six to eight years to build or produce in the hardware stage. These people who are designing these aeroplanes which could fight at that speed six or eight years later know all the answers. To me that is a very good way. When you produce an aeroplane, a particular type, it takes from six to eight years when you have finished it. It is in the hardware stage. If you have made a big mistake by that time then you are way behind. You have to start all over again. Research of that type is necessary in any Air Force, the same as research in the petroleum industry or any industry that hopes to stay ahead of its contemporaries or other people in the same business as they.

The maximum Mach number that we got out of the old X-1 in 1947 was a Mach number of 1·5. It turned out to be just about 1,000 m.p.h. at 46,000 ft. which was the altitude we achieved at the highest Mach number. The highest altitude we got the X-1 in 1948 was around 70,000 ft. Now back in those days you might say we were doing a lot of research work, not only on an aeroplane but on personal equipment for the aviation medicine people. I will run down here on what the human body requires to live or exist in these atmospheres. Here at sea level you are breathing air about 80 per cent nitrogen and various other gases and about 20 per cent oxygen. As you go to 12,000 ft. you still have the same ratio but since the pressure has dropped you are not getting enough oxygen to keep you normal, so a normal person has to start breathing oxygen, or supplementing the air he is breathing with oxygen. When you get up to 33,000 ft. a pilot or any human needs 100 per cent oxygen to breathe in order to keep him normal and if you go higher you have to start pressure breathing, otherwise putting pressure into the lungs to force oxygen into the blood stream at a rate which you are used to here at sea level. When you get up to about 46,000 or 47,000 ft. the pressure required to keep you normal is so great that your rib cage will not stand it, otherwise it will burst, so you have to start supplementing the human body with certain garments and/or materials to keep you stout enough to withstand this high pressure. So we developed the T-1 pressure suit. Back in 1946, prior to flying the X-1, I was working on a T-1 pressure suit in the aero-medical laboratory at Wright Field in pressure chambers. By the time we had the X-1 ready our pressure suit was ready for use in aeroplanes also. Anywhere above 50,000 ft. if you have a cockpit pressurisation failure you are a dead duck if you do not get down immediately, or have a pressure suit on. When you are doing research work and possibly going at a climbing angle at quite a rate of speed and something happens to your pressurisation you cannot come down immediately; you are going the way you are headed for a while till you slow down a little bit. So on all flights in the X-1 above 50,000 ft. we had to wear this awful suit. Actually you can compare it to a corset all over. It is quite uncomfortable to wear. It was in those days, but it

has been perfected and has points on it ironed out now until it is pretty acceptable today. In our tactical units or F-100 outfits, any time the pilot flies above 50,000 ft. he has got to put the T-1 pressure suit on because if he did not have it and he had a cockpit pressurisation failure that would mean we would lose him, and the aeroplane, so it is a necessity.

I made the last flight in the X-1 in 1949. A ground take-off. The aeroplane had originally been designed to take off from the ground but since it only had two and one-half minutes of fuel with all four chambers on, by the time you got up to the altitude where you wanted to do the work, you were out of fuel. So dropping it was the answer, but we wanted to make one ground take-off just to see if the aeroplane would do it. We only put one half a tank of liquid oxygen and half a tank of alcohol in it and dragged it off down to the south end of this long dry lake we have.

To give you an idea what a nice natural resource this dry lake is at Edwards Air Force Base, you have heard a lot about it and you have probably seen some pictures, but to me that is the most natural asset to flying research aeroplanes that there is anywhere in the world. Actually it is an old lake bed and being in the middle of the Mojave desert it is quite dry. It is hot and the weather is clear 365 days out of the year. We are never bothered with weather. This lake surface is made of a clay silt. It is as hard as concrete, and you can run aeroplanes over it weighing more than 400,000 lb. and they won't even leave a track on it. So you can see how hard the surface is. Now the year round we use this lake; we have marked off runways on it with black oil to where they stand out nicely. Since we do a lot of flying off it with research aeroplanes, we sometimes land on it without gear, make holes and cut it up, then it becomes quite rough. Each year in January it rains about 4 inches of water in the desert. Each year this 4 inches of water lies there and the wind blows about 50 miles an hour and it whips the water back and forward across the lake and the water dries up and you have got a completely new surface for the remainder of the year. This may sound unbelievable but it is the truth. It is a real natural lake bed or runway for landing aeroplanes on. When you hit the ground at 300 or 400 miles an hour it takes three or four miles to stop.

After the X-1 was finished up in 1949 we turned the aeroplane over to the Smithsonian Institute where it is sitting today with the Kitty Hawk and the Spirit of St. Louis. And in my career, the biggest thing that happened to me was being able to fly that particular aeroplane through that phase because it was most interesting.

As I said before, our research and development programme was based on trying to stay ahead of the speeds of normal production aeroplanes, and the next aeroplane they came out with was a contract for the X-4 at the time. When we use the letter X in front of a number it just means that aeroplane is to be used for research purposes only, it is no good as a weapon, you cannot fight with it, you cannot put on air shows with it. It is to be used for research purposes. So they came out with the X-4 which was very much along the same design as the DH-108, I think, the de Havilland Swallow. It was semi-tailless; it had a vertical stabiliser but did not have any horizontal stabiliser and it had ailerons that gave both lateral control and longitudinal control.

We flew this aeroplane back in about 1949 and got up to about 0·94 Mach number at which time the aeroplane would begin pitching, yawing, rolling at the same time and if we had taken it any faster it would probably have come apart on us, so as we liked our necks better than the contractors did, we quit. We completely exhausted the aeroplane's capabilities so far as we were concerned, speedwise and altitudewise and that was our job. Since it was a research aeroplane they junked it—I use the word junk loosely there because actually it takes a lot of man hours and money to support a research aeroplane, and when that aeroplane is completely exhausted you might as well take it

Courtesy of U.S. Information Service.

A T-1 pressure suit of the U.S.A.F. Rubber tubes along the arms and legs are inflated during high altitude flight. Tubes tighten laces and apply pressure evenly over the pilot. Oxygen hose and microphone are fitted to the plastic helmet.

out and give it to some school and let some school kids climb over it, because if you expect to keep it around and fly it, it takes a lot of man hours to keep it in commission so you might as well drop it right there because it is not going to do you any more good.

Then they came out with the X-5 built by Bell. This aeroplane was capable of sweeping its wings 20 degrees to 60 degrees. That aeroplane was built mainly to do a little research on Mach drag by varying degrees of sweep in the wings. That aeroplane would do about 0·82 or 0·84 Mach number with the wings in the forward position straight and level, and it would do about 0·94 with the wings in the 60 degree swept position, which showed us the difference in Mach drag. They also got

a lot of data on the stability of the aeroplane under various gust loads at various angles of sweep. I keep harping here that such programmes cost a lot of money and they cost a lot of man hours and there is not one lone individual who would be responsible for success. It takes a lot of work on mechanic's, engineer's and pilot's parts to completely bleed the data out of these aeroplanes.

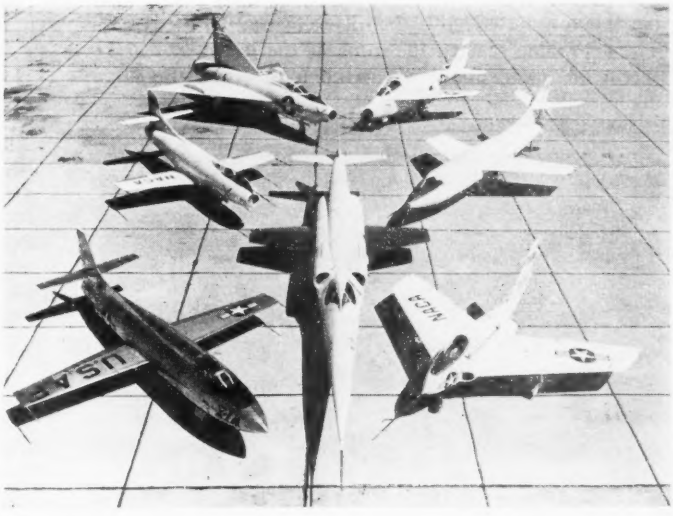
You may wonder why the X-4 and X-5 came before the X-2 or X-3, but as you know, some aeroplanes are more simple to build than others, so when the Air Force lets a contract, our first contract for a research aeroplane would naturally be called X-1, the second contract be called X-2, the third X-3, and so on like that, but since the X-4 and the X-5 were relatively simple aeroplanes to build around a jet engine with the basic principles, then it took only a few months to produce them. They came out before the previous contracts that were let.

After the X-5 was finished, they came out with the later version of the X-1 and as I said before they had these two spherical tanks, one of which held 288 gallons of liquid oxygen and the other 300 gallons of liquid oxygen and since you had to put very high pressures on these tanks, say of the order of 310 lb., the walls of the tank had to be very thick and consequently were very heavy, so in the later model of the X-1 the pumping system was changed. Instead of having these heavy walls and forcing the fuels back to the motor at very high pressure we put in a small turbine pump. To power this pump we used a 90 per cent solution of hydrogen peroxide. We could keep our liquid oxygen in a tank under about 40 lb. pressure. We could use, say, 24S-T or 1/16th inch Dural or Aluminium for the walls of the tank, which were very light, very thin. We did not have to have high pressures in the same way with the alcohol tank and in order to get the alcohol and the lox back to the motor we took our hydrogen peroxide (and as you know hydrogen peroxide is a very potent fuel) and we ran it over a catalysis crystal which caused it to turn to steam. It expands in volume about 1,000 times and this expansion of steam we used by running it over a turbine which is connected to two more turbine pumps by a drive shaft, and by turning it up we pumped our liquid oxygen and alcohol back to the motor at a high enough capacity or rate to satisfy the requirements of the engine. That gave us a lighter aeroplane and in addition we could have more room for fuel and Lox.

They called that aeroplane the X-1 No. 3, since it was the third X-1 built. The second one was practically the same as the first one except that it had thicker wings to get the difference in Mach drag on a 10 per cent wing in relation to the 8 per cent wing which was on the first aeroplane. The aeroplane No. 3 came out but that aeroplane never did make any flights. By increasing our fuel capacity from 288 gallons of liquid oxygen we put 500 gallons of liquid oxygen: instead of 300 gallons of alcohol we put 550 gallons of alcohol, which gave us enough fuel for running our same motor $4\frac{1}{2}$ minutes, so we almost doubled our duration.

Actually we made ground runs on the aeroplane: everything checked out O.K. except that on its maiden powered flight when we took the aeroplane up to 30,000 ft., we discovered that we had lost our nitrogen source, the pressure we used to raise and lower the flap and pressurise the cockpit and everything else. We had lost it due to a rupture in the line somewhere, so we came back down to 10,000 ft. at which time there was a big explosion back in the rear end and the X-1 pilot jumped out of the X-1 up into the bomb bay of the B-29 and the B-29 pilot went to help the X-1 pilot out of his cockpit and they had a collision in the doorway so they got all unscrambled and by this time the X-1 was burning quite merrily so they reached up and jettisoned the X-1 from the B-29. It fell away and blew up and we came on home and landed, so we lost that one.

They came out with another one. This did not happen at the rate that I am telling it. It takes a little time to build these aeroplanes. They came out with



U.S. experimental research aircraft at Edwards Air Force Base. *In the centre*, the Douglas X-3 jet-powered aeroplane; *left to right* around the X-3, the Bell X-1A rocket-powered aeroplane, the jet-powered Douglas D-558, the Convair XF-92 delta wing configuration, the Bell X-5 variable wing aeroplane, the Douglas rocket-powered D-558, and the twin-jet Northrop X-4 aeroplane.

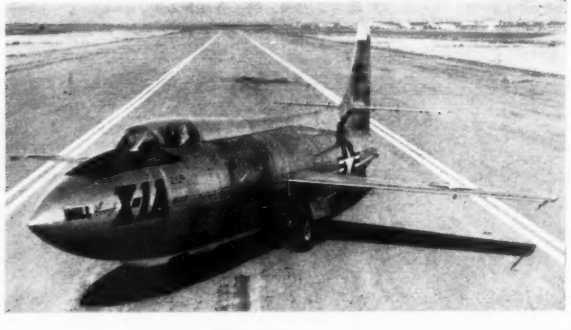
Courtesy of the U.S. Information Service

another aeroplane, the X-1A series, which Bell produced. It was practically a duplication of the X-1 No. 3. It had the same type of turbine pump and the same type of fuel and lox system, carried the same amount to be exact and, in fact, it was just an identical aeroplane.

I was assigned as the project pilot on that aeroplane; I flew it on four flights. This was in November 1953 and since 17th December was to be the 50th Anniversary of Powered Flight, all of our powers-that-be said it would be real nice if we could get up to above Mach 2 before the 50th Anniversary of Flight, so, little realising the commotion they were causing among the people who work, they say "Do it," so we done it.

The aeroplane was on quite an accelerated programme. The idea was to get the maximum performance out of this aeroplane and all of our long-haired engineers got together and figured out the step-type flying which the flight plan called for; dropping out at 30,000 ft., lighting off three of the four chambers available, accelerating up to 0·8 Mach number, climbing at 0·8 Mach number to 45,000 ft., firing the fourth chamber, levelling out, accelerating up to 1·1 and then going through a climb schedule that they gave you on up to a certain altitude and level off and let the aeroplane run till it ran out of fuel.

On the first flight, in practising for this type of the profile mission, they dropped me at 30,000 ft. and I fired off three of the chambers, went on up to 45,000 ft., fired off the fourth one and the aeroplane reacted exactly in the same way as the old X-1 did since it had the same wings, same tail, practically the same fuselage, only 7 feet longer. It reacted practically the same way by getting into buffeting at about 0·88 Mach number, getting wing roll and losing elevator effectiveness at about 0·94, but we used the stabiliser to increase our angle of climb or adjust our flight path. Then after you get up to about 1·1 your aeroplane smooths out, your buffeting drops away, your aeroplane trims up again, the wing will raise the one it dropped and you can get your elevator control back again, or it becomes not quite as effective as it was down around 0·8 Mach, but much more effective than it was from 0·94 to 1·05. The aeroplane reacted the same as the initial X-1 as I ran it on up to about 1·3 Mach number on the first flight.



The Bell X-1A.

The second flight was at about 50,000 ft. The second flight was identical to the first right on through the steps, except that I took it up to 50,000 ft., let it sit till it got up to 1·5, shut it off and jettisoned the remainder of the Lox and fuel and came on down and landed. We looked at our data and I pretty well had the flight plan down perfect, which was the most important.

The third flight ran the profile, instead of going on upstairs on above 60,000 ft. I levelled out at around 60,000 ft., held it straight and level and ran it up to 1·9 Mach number, which is about 1,200 m.p.h., shut it off and came down and landed.

The fourth and last flight actually was on 12th December; we beat our schedule a little ahead of time. We dropped the aeroplane out at 30,000 ft., ran through our mission right on up. At 45,000 ft. we had them all four going; went up to about 1·1 Mach number and started climbing; went through 50,000 ft. at about 1·15; went through 60,000 ft. at about 1·4 and I was supposed to start levelling out or pull zero g's or flight in a parabolic curve, starting at 61,000 or 62,000 ft., but due to the excited nature of the pilot I over-shot. Actually I got to around 68,000 ft. before I started pushing over, came level at 78,000 ft. and was indicating about 1·9 Mach number at that altitude and I had a few seconds of fuel remaining. I held it there straight and level and the aeroplane was accelerating at a rate of 31 m.p.h. each second, every second it ticked off you gained 31 m.p.h., that is about six hundredth of a Mach number each second. You are really knocking it off in a hurry. The aeroplane ran out of fuel at about 76,000 ft. and at a Mach number of a little better than 2·5. Our instrumentation is accurate to within about one half of one per cent at 2·51, or 2·52, give or take a half of a point there, we get a true air speed of a little better than 1,650 m.p.h. The indicated air speed, of course, as you know since the air is so rare, it was only around 440 m.p.h.

Actually the X-1A you might say was not designed for that sort of flying. It was designed for Mach numbers of about 2. We over-stepped our bounds a little bit, since the aeroplane does not have a flying tail on it, it does not have boosted controls. When a body or an aeroplane accelerates it has induced stability due to acceleration you might say. When I shut off the power, or ran out of fuel, the aeroplane started decelerating and at that point we lost all stability, or rather the stability completely deteriorated on the aeroplane and having very little control of it, the aeroplane started more or less changing ends, so we had a moment of anxiety there. The aeroplane got up to some pretty high rates of roll and yaw and pitch angles. The aeroplane started rolling to the right to start with, so I put all the controls against the rolls, like they taught me in flying school, and it did not help so I put them with it and it did not help. I let them loose and started praying about then. The aeroplane had got some pretty high accelerations, high yaw angles—actually this took a lot longer to tell than it took to happen. The aeroplane was going 1,650 at about 76,000 ft. and 51 seconds later settled at 25,000 ft. and 170 m.p.h., so I

had not got much time to fool around. The aeroplane evidently started becoming stable as it slowed back down to a range of a Mach number of 2. I had pulled the stabiliser down in trying to slow the aeroplane up and I did not know what part of the high Sierras I was going to hit into out there and was trying to get in a little closer to the lake. The aeroplane finally pulled about 11 *g*'s upwards, tried to stabilise itself and of course then started snapping and I was pretty well blacked out due to the high acceleration forces. Finally it did slow down to below Mach 1 and came down to 35,000 ft. I rolled the stabiliser in but I over-shot and the aeroplane got into an inverted spin, so then I got my eyeballs caged and came back to neutral, put everything with the inverted spin and flipped into a normal spin and I recovered at 25,000 ft. and glided on back to the lake and that was the last flight I made in the aeroplane.

Later on the aeroplane flew with Major Kit Murray flying it and got up to altitudes in excess of 90,000 ft., dropping at 30,000 ft. and running through this same profile but keeping his Mach number below 2. As the aeroplane went on up, of course, it got into rare air, and he would run into a little bit of instability but by having his Mach number low he was able to control it. After the aeroplane was more or less exhausted in its capabilities, some of the other pilots flew it and we never did much above Mach 2 after that, due to the loss of instability that would occur and about six months ago the aeroplane went the way of the other X-1 No. 3. They had it at 30,000 ft. except it did not give any warning. It blew up at 30,000 ft. and fortunately enough the pilot was able to jump out of the cockpit up into the B.29 and they jettisoned it and it fell away and there was a larger explosion and it disintegrated, so we have the aeroplane no more.

But at those speeds we are getting into areas where we are running into temperature problems as far as aluminium is concerned. The aeroplane, if it had flown, say at 1,650 m.p.h. for five or ten minutes, would have started losing pieces of the aluminium due to structural failure, due to temperature rise. Now the X-2 which is flying today is a more refined aeroplane, I would say. It has swept wings; it has block trailing edges; the leading edges are extremely sharp; a long sharp nose; it has an engine which is three times as powerful as the one I had in the original X-1. That aeroplane is designed to fly in the order of around 2,000 m.p.h. Now to get away from the temperature problems the aeroplane has a skin made of K Monel stainless steel so that it will withstand much higher temperatures.

A lot of people use the expression of so-called "Thermal Barrier." Now there is no thermal barrier as you would think of it. Actually every aeroplane has its own limit for speed, due to temperature rise. So that if an aeroplane is made out of wax it will melt at about 300 or 400 miles an hour. If it is made out of aluminium your limits are in the order of 1,600 to 1,800 miles an hour. If it is made out of stainless steel it is probably in the order of 2,300-2,400 miles an hour. If you make it out of metals, say like Titanium or other alloys which are very good and heat resistant, it will probably go faster. These are the main components of the aeroplane which are exposed to such temperatures, such as the nose, the leading edge of the wing and the leading edge of your tail surface. Actually beyond that, thought is being given to making those portions of the aeroplane, or coating them, with a ceramic type coating such as china, as dishes have on them. It will withstand extreme temperatures without a loss of structure but that is a matter for the future. To build aeroplanes like that is not as simple as getting up here and telling about them. It takes many years of work and research to make everything pan out in the end.

Now, how the human body stands with the aeroplane; you have got a cockpit, it is pressurised; the pilot is wearing protective clothing. The big problem we are faced with now is saving the pilot's life when he has to get out of one of these machines at high speeds and high altitudes. It is a problem we are faced with today and everything is being done as fast as possible but it is a big problem. A lot of people are going to get killed before they get it solved. That is one of the costs of progress as you might say.

Now that is about all the confab that I have memorised so I think we have had a very informal meeting here. I think it is a good attitude and if there are any questions to be asked I will try to answer them. You must remember that I am in the United States Air Force and I am a Lieutenant Colonel and I am not the boss of the Air Force. There is always somebody that is larger than I am, so I cannot answer questions that fringe on security and I cannot answer questions about the policy that the United States Air Force or our State Department lays down. Just remember that when you ask questions.

DISCUSSION

P. J. B. SOLOMON (Imperial College): Colonel Yeager, I read I think once in "Life" magazine that you had experienced free fall. I do not quite know what free fall is so would you mind explaining it and also the sensation that you endured.

COLONEL YEAGER: They used the expression of free fall as gravity free flight. Now when you get out of the earth's gravitational field, you have nothing pulling on you, you are floating you might say. Now you can simulate that. Everybody that has flown can do it for an extended period of time of course. An aeroplane that will do 650 m.p.h. will actually have a capability of pulling zero *g* by flying a parabolic curve. So your curve is like this and the centrifugal force of the path of the aeroplane equalises the pull of gravity and give or take a little bit of force air due to longitudinal acceleration or deceleration on the other side, you are

practically in a gravity free flight. Now many organs of the body depend on gravity to function properly, and the sensations—I do not know, everybody has a different attitude about their own feelings. I, particularly for the first few times that we were doing it, had to depend on my visual senses in order to keep orientated. After you do it a few times you become acclimatised to it.

If and when there ever gets to be space flight of course it will be under gravity-free conditions but you can simulate gravity if you are in a big missile or in a big machine that goes two million miles out into space. It will be big enough and we can rotate it maybe 100 odd rotations per minute and you will have one tenth of a *g* centrifugal force, you can walk round the walls which is as good as one *g* so actually I do not see that a great problem is involved.

PETER TWISS (Test Pilot, Fairey Aviation Co. Ltd., *Associate*): This is rather unexpected. It has been a most interesting talk we have had from Colonel Yeager about a phase of flying that we have not got into in this country. We are on the fringes of it at the moment perhaps but the Americans have been way above, both in altitude and in performance in my experience. There is just one thing I would like him to make a few statements on. We are very much lacking suitable instruments to give the pilot the data to enable him to carry out flight tests of that kind with some ease; things like Machmeters and horizon instruments are very much behind the aeroplanes themselves and I would like to ask Colonel Yeager whether his experience on the research aeroplanes he flew was the same as is ours today.

COLONEL YEAGER: I am glad you have called someone up here beside me. It is indeed a pleasure to be associated with Peter. I have read quite a bit about him in the last few weeks and he seems to be a very capable individual.

Actually our big problem today is giving, as you say, a proper presentation to the pilot of what his aeroplane is doing, specially in research flying, since you are flying extremely high performance aeroplanes at very high angles of climb. Some of them are approaching the 60° angle and with the vision that we have in the cockpit you are sitting up at an angle like that; you cannot see the ground and all you can see is blue sky and you do not know how much of it you have gone through. One of the tricks that I found paid off tremendously, the same as Bill Bridgeman used in his D-55-8, to get these proper angles of climb, was using, I think they call it an Inclinometer, which gives you the angle of attack that the aeroplane is flying in relation to gravity. It is fine on a straightaway approach up to 70 and 80° angle of climb. The same way as with our modern day fighters, there was getting to be quite a bit of a lag in Machmeters, in air speed indicators and altimeters due to the high performance of the aeroplane and due to the high volume in the lines that you have got to send away after on the nose to pick up the static pressure and the impact pressure, so it seems that we are going to have to go into electronic type devices to transmit the true picture from the, say Pitot head, or the air speed boom, through the instrument to get away from this high lack due to the volumes in the lines. There are one or two problems that we have been faced with and have licked by using that type of instrument. There is a very big problem and it is not a matter, as I said before, of building an aeroplane; you do not do it by talking about it, it requires a lot of work on a lot of people's parts.

SQUADRON LEADER NEVILLE DUKE (Chief Test Pilot, Hawker Aircraft Ltd., *Associate*): It is an unfair suggestion to get me up here but as Sir Sydney is my boss I can hardly refuse.

I too enjoyed your talk most sincerely and it was very interesting indeed. I feel that you have the resources and facilities in the States which we lack rather in this country, in weather factors as well as your admirable flying facilities. But in spite of all those things I do not think we can be excused for the fact that we have such little experience of rocket propulsion in flight in this country. To my knowledge there is only one aircraft in this country that has ever flown with any rocket assistance at all and that was back in 1948 or 1949. Some half dozen flights were then carried out but none have taken place ever since, which I think is an extremely sad situation. You do not require large facilities on the ground to operate such a combined power unit as a jet engine and a rocket motor for research purposes.

One further interesting point which arises from the American experience is that they, back in the middle War years, were obviously going to proceed with this type of research and even at that time, hard pressed as everybody was, they were planning these machines which, as Colonel Yeager says, take some five or six years to become airborne. We were engaged on other activities which took all our resources but since then I feel that sufficient attention has not been paid to the problem, which he illustrated by stating that you must lead in research by some five or six years in order, at the end of that time, to have information available to build aircraft for service use, which will be up to date with contemporary fighters or bomber types designed by other countries.

A further point very near and dear to all who do any of this flying is the question of survival at the higher speeds which we are approaching now with indicated speeds in the order of 800 knots or more in the not too far distance. I feel in spite of the excellent facilities provided by the ejector seat and such equipment at the moment, that that is not adequate, and a certain unfair duty is being imposed on the pilot of the near future to be expected to tolerate those conditions indefinitely. I would like to see much more attention and research in this country on that problem. Much goes on in the States but little I see here.

I fear I have no trick question to ask you but would like to thank you again most sincerely for a most interesting talk.

GROUP CAPTAIN R. G. SLADE (Chief Test Pilot, Fairey Aviation Co. Ltd.): This call to speak is even more

unexpected! Two pilots from one Company is a little unfair on you.

I enjoyed Colonel Yeager's lecture very much indeed and would prefer to think it over rather than discuss it immediately. But, as Neville Duke said, it is astonishing to realise what was planned and achieved in America before we poor, penniless Britons managed to do anything at all; and to realise that a Mach number of 2·5 is still well beyond our immediate reach. However, the opportunity to attain these speeds is coming our way in the near future and this country must be in the swim as well as America.

What I would like to ask Colonel Yeager—in view of his experience at speeds that were rather superior to what had been planned and to those for which his aeroplane had been designed—is whether the engine, or power, control must be so arranged that some power is always held in reserve? This would be intended to ensure that thrust was cut down progressively at the end of an acceleration and thus reduce the risk of running out of stability at the high Mach number he reached, a problem which will soon be within striking distance in this country.

Another question which is a corollary of the first is: Can he say what change of longitudinal trim he experienced during the acceleration from 1·5 to 2·5 Mach number in level flight; if he was not directly aware of it at the time owing to the rate of acceleration, what did the telemetering measure?

COLONEL YEAGER: Well sir, in relation to your first question, when it concerns a research aeroplane there is a possibility that we would not have run into so much trouble at the end of our fast flight had we been able to bleed our power off gradually and come to a stabilised condition and then decelerated, but since performance is the primary goal of that sort of flying we wanted the aeroplane to go as fast as it possibly could. Not knowing that we would run into this problem we went ahead as fast as it would go until we ran out of fuel and then it quit immediately. Actually, with production aeroplanes in the order of the F-100 or 101, 102, 103 or 104, which are getting up into quite high Mach numbers, I have noticed that it is very hard on the pilot's sense of balance, or you might say sense of well-being, sitting in an aeroplane driving along at 1,000 m.p.h. and suddenly cut out his afterburner and the deceleration is very confusing, especially if you are flying by gauges in weather or trying to do any type of concentration on your instrument panel. The deceleration immediately there causes you to become disorientated as far as your senses are concerned.

Now there is a lot I cannot answer in the order of trim changes. I would say this, that in the X-1A, you must remember, going straight and level, actually we became level at about 1·9 Mach number and quit at 2·5, but accelerating in the other flights previous to that, about 1·1 up to about 1·9, other than anticipating the trim change by changing the angle of incidence on the stabiliser, otherwise we had to change it by 1½° nose down which we had, it dropped to 2° nose down which would occur after we got supersonic. Beyond that the trim remained the same, about 1·1 on up to as fast as we took the aeroplane, the longitudinal trim which may be true on that particular aeroplane but may not be true on another different design of aeroplane. I am not talking about aeroplanes in the category of the 101 or the 104, I am talking about the particular aeroplane, the X-1A, which had no longitudinal trim changes above 1·1 whatsoever.

GEORGE EDWARDS (Vickers-Armstrongs Ltd., *Fellow*): Well sir, this is also unexpected but I would like the opportunity, now I am in the presence of such an illustrious gathering of test pilots, to pick up the point that Neville Duke made and just say this. That those who are in the Aviation business, whatever job we do, taken by and large, we all think it is a pretty hard life and that we are all going to come to an untimely end due to overwork. Most of this of course is exaggerated self-pity but nobody in the chain really puts himself into any personal danger other than the test piloting part of the chain. I think it worth a moment's reflection that out of all of us who are having such a rough time the only chap who deliberately and knowingly puts himself in personal danger, in order to show how wrong the theorists in fact are, is the test pilot, and that is the one thing we ought never to forget. The other thing is that the least we can do is never to miss an opportunity to see that he does not come to an untimely end, and I think that if there is anything any of us can do—however inconvenient or difficult or awkward it might be—which increases his chances of getting away with it when the theorists are wrong, we should never miss the chance of doing it. I think that the best pilots of your country and of this country deserve a solemn vote of thanks from those of us who are in the business detached from the popular spectacle which confronts test pilots, and further, I think that there is no more practical way of showing it than the one I have just intimated.

The other reflection which I have in listening to that amazing discourse, which has been given without a note, is regret. That the great wealth of supersonic flight which the Americans have compared with that which we have not, regret, tinged by pleasure at the fact that, at the moment at any rate, they are on our side, and the determination that at all costs we have jolly well got to keep them there too!

COLONEL YEAGER: I think I can, on behalf of Neville and Peter, say thank you. We are pretty humble. One thing that I would like to clarify here is that we have been extremely lucky in our research and development programmes, and I think you all know better than I do that the initial attempt back in the early days after the War of your research and development programme ended up with a lot of fatalities due to bad luck. It really threw a wet blanket over your research and development programme. That's known. We were extremely lucky in that we did not lose any pilots during our research and development flying. I am extremely happy of that myself. But fate plays a lot in one's position when it comes to such things so we were lucky

that things turned out like they did. And so we have much better facilities for doing that sort of flying and it is not the ability of the pilot or the engineers.

I can stand up here and say, and I do not think I would be bucked by Neville and Peter, that I happened to be in the right place at the right time. Ninety per cent of the pilots in our Air Force, or your Air Force, or anybody else's Air Force, could have flown the X-1 or the X-1A, and I think that ninety per cent of the guys can possibly hack the Fairey Delta 2, because those guys are trained for that. If you can get an aeroplane off the ground and on the ground again, due to the smartness of our hairless long hairs, those guys have the know-how. They have given us a piece of machinery which we can do the job with. It makes it a lot easier so that it falls within the category of our pilots who have been trained for that sort of thing. So I think there that we are not martyrs or anything. That is our job and we just do it the best we know how and consequently luck plays a big part in it. Thank you.

E. T. JONES (Principal Director Scientific Research (Air), Ministry of Supply, *Fellow*): I have known Colonel Yeager since 1948 and I have known of the work he has been doing ever since that time. I have heard him speak on this subject I think three times before and believe me, he has not, as he has indicated, got his lecture off by heart because each time his story covers different aspects of the aircraft design and of the flight information which these research aircraft have given.

I would like to make one point which has a bearing I think on Mr. George Edwards' remarks. Colonel Yeager mentioned in his lecture that these X-1, X-2, and so on, aircraft are of extreme simplicity in that they do not contain ejection seats, powered controls and the high degree of all-weather flying instruments which we in the United Kingdom expect to find in supersonic aircraft. Colonel Yeager explained that the pilots themselves were consulted before the aircraft were designed and they were able to throw away many items of equipment and instrumentation which would otherwise have been necessary because of the landing facilities and good weather which existed at the particular location in which the flight tests were to be made. For example, it is comparatively easy on a dried sea lake like Muroc, which was available to Colonel Yeager and his colleagues, to land these aircraft as gliders irrespective of the wind direction. We in this country do not have the natural facilities of Muroc which were available to Colonel Yeager and his colleagues and the best landing ground we had available was a runway 2,500 yards long and 100 yards wide. I do not think that pilots in this country would have agreed to do away with the equipment which the Americans were able to throw overboard and yet feel confident of landing "dead stick" in the weather conditions that might obtain in our country. This I feel is one of the main reasons why our policy has been different, and not having available another aircraft of the size of B-29 we had to construct research aircraft with most of the built-in facilities of operational aircraft.

However, with the information that Colonel Yeager has given us tonight we should consider whether we in this country are not designing our research aircraft in a more comprehensive manner than is necessary for the job they are required to do. We might, for example, take a bit of advice from the pilots union in America and make these aircraft more simple, which would undoubtedly take less time and cost less money.

I would like to know whether Colonel Yeager thinks that the simple aircraft he has described would be practicable for operation from normal runways.

COLONEL YEAGER: We have had quite a discussion at various and sundry meetings. I think I stood up with Neville Duke at the A.G.A.R.D. meeting at The Hague a couple of years ago and we discussed with all of the more or less engineering members of the N.A.T.O. countries about the simplicity of an aeroplane. As you know, when you specialise in aeroplanes in these days of much know-how and technical advancement, if you want an aeroplane that will go up and intercept an enemy aircraft and shoot it down you cannot fix that aeroplane so that it will carry bombs all the way across the Atlantic or the Pacific on the deck. What I am getting at is that if you want to make the best fighter in the world that aeroplane can only fight. If you want to make the best bomber in the world that aeroplane can only be a bomber. You cannot mix the two because with the advancements in technology or the advancements in science, if you penalise that aeroplane one degree then it is not as good as the other man's aeroplane who is making a fighter which is only for a fighter. And our big bone is that we hate to get in an aeroplane that is built for about four different purposes when you are only flying it on one mission and if that particular mission just happens to be for one purpose you are only using one fourth of the thingumajigs they have in the cockpit, so you penalise the aeroplane by carrying so much stuff on it. Now our country possibly does that more than yours does by having dual purpose aeroplanes, because our economy will not support specialisation in time of peace; in time of war it is not hard to get money but in time of peace it is, believe me.

I thank him for the compliment of my talks. I thought he meant that I changed my story every time. Actually it is very hard for me to give a talk and say the same thing over and over again. It gets boring and I actually talk to amuse myself as much as I do you. That is the reason I may seem so happy. Actually I am scared to death.

SQUADRON LEADER EVANS (*Associate Fellow*): I am not quite clear why this instability occurs when you accelerate beyond a specific Mach number. Could you give any indication of which are the main points—is it the acceleration or the Mach number or a combination of both?

COLONEL YEAGER: Actually, a lot of things enter into our loss of control of the X-1A at its maximum Mach number attained. As I said before, not having

boosted controls you run into tremendously high control forces and if an aeroplane is not symmetrical, I mean both wings are identical in profile and everything, you have a tendency to get trim changes and such and when you have not got enough force to over-control these trim changes and then suddenly you end up with an aeroplane that you are counteracting, say, trim changes with your controls, then you have a loss of stability. It is like flying an unstable aeroplane without any controls at all and that is just a rough picture of what happened. Now Mach numbers, I cannot give you forces, Mach numbers, positions and yaw angle, because that type of specific information is classified and not to be disseminated to those people, I think the regulation says, that are not due to hear. That is about all I can give you on it. I am not an engineer and I do not know such things; even if I did I could not tell you so.

K. BRADING (General Electric Co., Stanmore): I should like to ask Colonel Yeager about this condition of zero g or free fall that was talked about first of all. Mr. Bridgeman has described various symptoms when he reduced his g to as low as 0·2 and found it necessary to limit it to 0·5 due to loss of longitudinal stability in the aircraft. Was the X-1 also affected in this way?

COLONEL YEAGER: The particular X-1, you see it is a known fact I think with conventional-type aeroplanes, that if you are flying straight and level pulling one g, if you have a slight loss of static stability, actually your stability will increase if you increase your lift coefficient. Now I have found with the biggest majority of aeroplanes that I have flown that if you increase the lift coefficient, or the load factor there from one g straight and level to, say, 2/10ths, you do get a deterioration of stability about the aeroplane, and Bill's problem, which fortunately we were not faced with with the X-1A, was this pushing over. Now I could have picked up some more speed possibly after I levelled out at, say, 78,000 ft., by dropping the nose gradually and holding zero g right on down, but I did not want to get into the lower atmosphere where the air is heavier and drag would build up high. I wanted to stay up as high as I could in order to pick up the speed since I was in a region that I knew very little about. Bill's problem of course in his speed, was to bleed the maximum and by having a swept-wing aeroplane he did not go as high as we did in our speed runs. He would have to push over and fly this parabolic curve from the time he hit his climb speed until he ended up his fuel and his 60° dive to get maximum performance. I think it is rather prevalent in swept-wing type aeroplanes, or delta wings, which is the same as the swept as far as lateral stability is concerned, if you do decrease the lift coefficient on them you do run into the instability problem if that is inherent in that aeroplane, but we did not experience it in the X-1A.

A SPEAKER: Mr. Chairman, may I ask Colonel Yeager whether it was very hot in the machine at any particular time of the flight. And, what kind of parachutes do they carry, with the mechanism?

COLONEL YEAGER: Since the duration of our flight was extremely short, if we had not run into stability we should probably have run into Plexiglass problems as it was used in the cockpit of the aeroplane at the time. As it was, we took the interliner out of it but that was not due to heat, it was due to force involved between my head and the canopy. There was no heat that I could sense because I was within 6 inches of any part of the aeroplane and, as I said before, I was sitting on a Lox tank or my back was against it, and it was extremely cold; I had on my red flannels under my T-1 pressure suit and on top of that I had an outer garment, a very heavy flying suit.

Unfortunately we had no ejector seat in any of the X-1's that I flew. There was no way to get out. I did wear a parachute but mainly to sit on. Of course we used the equipment that we had in those days and you must remember that the X-1 cockpit was designed prior to any ejection seat. We had no way of getting out of the aeroplane, no seats or such, all we would have been able to do was slow the aeroplane down and go out the side and I used to plan a seat type parachute in order to sit on it, it was softer than the metal floor. And today, although in our modern-type fighters we have practically the same system that is used in your high performance aeroplanes, I think, incorporated with your Martin-Baker seats. We have practically an automatic system also in that you eject yourself—the Navy used the blind type, we use the arm rest. Probably if you incorporate them both in the same seat it would be better—if you got negative g you could reach up here, if you got positive g you could reach down here. Two seconds after the seat leaves the aeroplane the lap belt opens; two seconds after the lap belt opens the parachute will open if you are below 15,000 ft. If you are above 15,000 ft. your aneroid cell will open the parachute below 15,000 ft. Possibly we would not have had a chance of survival in the X-1 or the X-1A if anything would have happened that we could not have got out of it because there is no way out unless you merely crawl out on your hands and knees, which is very hard under acceleration.

ANOTHER SPEAKER: Could Colonel Yeager give more details of the dead-stick landing of the X-1 and what his approach was to dead-stick landing?

COLONEL YEAGER: All jet pilots are faced with the problem of dead-stick landing sooner or later in their career, even flying normal jets like the Hunter or the Sabre and such. We practise dead-stick landing day in and day out in my squadron. That is in case you do have an engine failure, you are a little more familiar with the dead-stick landing characteristics of the aeroplane. Now the X-1 was lighter. The aeroplane touched down at around 180 miles an hour. I used to come across off the deck at anywhere around 400 or set up a 270 pattern overhead or 360 overhead and after flying the aeroplane a few flights, could usually hit within one or two hundred yards of my aiming point. With a pattern 300 knots I would come over my point with a 360 at 5,000 ft. above my point, haul the

aeroplane in, slow it down to 220 miles an hour on a down wind, put the gear down, hold 220 all the way round until I got on to the final approach, slow up to 200 and touch down at 180.

We have set up for all of our jet aircraft, simulated conditions for actual dead-stick landings. You can shoot a dead-stick landing, you say, in idle, the throttle in idle position, but idling will give you a certain amount of thrust so what do we do? We use the lake bed out there where we know we can hit and we take, say an F-86 up, put another F-86 on its wing, chop the throttle all the way off till your engine is just windmilling in the one aeroplane and then we open the dive brakes on the other aircraft, the wing man, and record the amount of r.p.m., the power it takes to stay on his wing. In that way we can give a pilot an r.p.m. or a condition with his dive brakes down which will simulate an actual dead-stick landing and let him run his practice with that power setting and it teaches him to become very proficient. We save quite a few dollars worth of aeroplanes on relatively short runways with a guy having practised day in and day out. It is a life saver, but aeroplanes are getting pretty complicated and it is nip and tuck as to whether or not I would ask one of my younger pilots to attempt to bring an aeroplane back, because if you miss it you do not fly any more—it is that serious in a higher performance aeroplane.

A THIRD SPEAKER: Mr. Chairman, we see that the N.A.C.A. are now said to be planning a research aeroplane designated the X-10 which, by coincidence, is supposed to fly up to the Mach number of 10. Can Colonel Yeager make any predictions about any new difficulties that are likely to arise in extending the speed range at that level?

COLONEL YEAGER: There are a lot of research aeroplanes on the drawing board right now that we will see in four to five years, with Mach number capabilities of 10. I take all things with a grain of salt. But actually I cannot see any problems whatsoever in aeroplanes that will fly that fast other than temperature problems, and if they lick those I am sure they will be quite successful because along with this advancement of speed comes the advancement of know-how, helped along with wind tunnels. Wind tunnels play an awfully important part in the design of aeroplanes, especially research aeroplanes where we have no data in that region.

Actually we have been here quite a while and I expect you are all as tired of sitting down as I am standing up. I sure will consider it an honour to have been invited over here to talk to such a distinguished organisation. I have heard an awful lot about you, I also want to thank Neville and Peter for being so patient and not putting me on the spot. I was glad to see that they were called up because it makes the job a little easier if you know someone else has to suffer along with you. I really thank you and if there is anything I can do besides give you money or aeroplanes I will be glad to do it.

SIR SYDNEY CAMM (*Chairman*): I must thank Colonel Yeager for a most excellent lecture very ably delivered, and also thank him for the marvellous way he has answered the points raised in the discussion.

I should like to conclude by saying a few words. The lecturer started off by saying that engineers scared him. Well, of course engineers scare themselves, but fortunately designers and engineers are not pilots, so I do not think they know the degree to which it is possible to be scared.

Over the years pilots have taken these risks. Nearly thirty years ago some very well known pioneers thought that speeds of up to 200 miles were just the limit of human endurance. We can thus see how, over the years, the capacity of the human body to take punishment has proved inexhaustible.

With regard to Mr. Neville Duke's points about pilots' safety, we owe a tremendous amount to the pilots who test our machines, as even with the best designs, best methods and best wind tunnel work, there still remain unknown factors which the pilots alone have to deal with, and so I should like to take this opportunity of recording my own feelings of gratitude to the noble band of pilots who, over the years, have given their time and lives to the advancement of aviation.

We are now contemplating speeds which will necessitate the utmost skill in design to provide satisfactory structures and—of equal importance—the maximum safety for the pilot.

Transient Temperature Distributions and Thermal Stresses in Fuselage Shells with Bulkheads or Frames

by

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SUMMARY: The temperature distribution and thermal stresses are calculated in a configuration consisting of a cylindrical fuselage shell with bulkheads or frames. It is shown that at supersonic speeds thermal stresses are set up in a conventional fuselage structure as a result of the bulkhead restraint against circumferential expansion of the fuselage skin. The thermal stresses due to restraint by fuselage frames are usually less severe. The relative merits of various combinations of materials for the skin and the bulkhead diaphragm are discussed. Furthermore, the possibility of the use of light alloy bulkheads to alleviate thermal stresses is investigated. Diagrams are given for calculating maximum thermal stresses and stress-time variation for various rates of heat input in the fuselage skin due to aerodynamic heating.

1. Introduction

The major structural effect of aerodynamic heating, apart from the deterioration of material properties, may be summarised as follows: the external surface of the structure of an aeroplane or missile accelerated to a high Mach number is heated by forced convection till it attains its equilibrium temperature, while the interior structure increases its temperature, mainly by conduction, at a much slower rate depending on the thermal properties of the structural material. Thus temperature gradients are set up within the structure, resulting in non-uniform expansions which cannot proceed freely, and thermal stresses are induced. So far attention has been confined mainly to wing structures, either solid or simple skin/web combinations, and the methods of thermal stress analysis of such structures are well known.[1, 2, 3]

The present paper deals with some aspects of aerodynamic heating and induced thermal stresses in typical fuselage structures. In particular, the effect of bulkhead restraint on the circumferential expansion of the fuselage skin is investigated. Because it takes only a relatively short time for the fuselage skin to attain its equilibrium temperature, the temperatures in the bulkhead and the skin will differ appreciably, giving rise to thermal stresses. If we visualise the structure cut apart, with the skin and bulkhead allowed to assume their unrestrained shapes, then these two components would expand by different amounts in the transient state. By application of suitable radial loads on each component at the skin/bulkhead joint, the two parts are brought into compatible shapes. These radial loads on the fuselage shell produce a stress distribution which is damped out with the distance away from the bulkhead/skin joint. Nevertheless, these localised stresses, when combined with stresses due to air and inertia loading, may become exceedingly high. Similarly, thermal stresses are also induced by the restraint of fuselage frames, but this effect is usually small.

The present analysis is restricted to cylindrical shells of revolution, with or without longitudinal stiffeners (stringers), reinforced by circular bulkhead diaphragms or frames. The general conclusions, however, are equally applicable to any type of shell of similar construction. The main purpose of this paper is to simplify and generalise the analysis of the aerodynamic heating problem in fuselage structures, so that the salient features may be clear and successful methods of alleviating adverse thermal effects may suggest themselves.

NOTATION

x	co-ordinate measured along the shell axis (in.)
φ	angle denoting position on the shell periphery
r	radius (in.)
R_0	fuselage radius (in. or ft.)
b	stringer pitch (in.)
A_f	frame cross-sectional area (in.^{2})
I	moment of inertia of the skin/stringer combination (in.^{4})
E	Young's modulus (lb./in.^{2})
ν	Poisson's ratio
d	skin thickness (in. or ft.)
D	flexural rigidity of skin, $=E_1 d_1^3/[12(1-\nu_1^2)]$. (lb.-in.)
m	$=\{3(1-\nu_1^2)/(R_0^2 d_1^2)\}^{\frac{1}{4}}$ (1/in.)
n	$=[d_1 b/(4R_0^2 I)]^{\frac{1}{4}}$ (1/in.)
t	time (sec.)
N_x, N_φ	stress-resultants in x and φ directions respectively (lb./in.)
Q	transverse shear per unit length (lb./in.)
M_x, M_φ	bending moments per unit length about φ and x axes respectively (lb.-in./in.)
P	radial reaction between the shell and the bulkhead diaphragm or frame (lb./in.)

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σ_r, σ_θ radial and tangential stresses on the bulkhead diaphragm respectively (lb./in.^{2})
w radial displacement (in.)
St Stanton number
h surface heat transfer coefficient (B.T.U./ft.^{2} sec. °F)
c_p specific heat of air at constant pressure (B.T.U./lb. °F)
ρ_a density of air (lb./ft.^{3})
V velocity (ft./sec.)
$\beta = h/(\rho_1 c_1 d_1)$ (1/sec.)
T_{ad} adiabatic wall temperature (°F)
T_i initial temperature (°F)
$T_0 = T_{ad} - T_i$ (°F)
T_s skin temperature (°F)
T temperature increase above the initial temperature (°F)
ΔT temperature drop across the joint interface (°F)
H_j thermal conductance of joint (B.T.U./ft.^{2} sec. °F)
K thermal conductivity (B.T.U./ft.^{2} sec. (°F/ft.))
κ thermal diffusivity (ft.^{2}/sec.)
ρ density (lb./ft.^{3})
c specific heat (B.T.U./lb. °F)
μ heating parameter, $= R_0(\beta/\kappa_2)^{\frac{1}{2}}$
N non-dimensional time (Fourier number), $= \kappa_2 t/R_0^2$
θ relative thermal resistance of joint $= K_2/(H_j R_0)$
S non-dimensional parameter (*see* equations (24) and (25))
S_0 non-dimensional parameter (*see* equation (31))
w_j roots of equation (11) or (13) (1/in.)
$J_0(\ ), J_1(\ )$ Bessel functions of the first kind of the order zero and one respectively

Suffices

1 shell
2 bulkhead diaphragm
3 frame

2. Skin Temperatures

Determination of the exact temperature distribution in a fuselage shell requires the simultaneous solution of the heat transfer and aerodynamic equations, which is only possible numerically. This is a time-consuming task and the results would have little general value because of the number of parameters involved. General information, however, can be obtained if several simplifying assumptions are introduced.

The heat input (per unit area) from the boundary layer into a thin skin is related to the mean temperature increase in the skin by the equation

$$\rho_1 c_1 d_1 \frac{\partial T_s}{\partial t} = h(T_{ad} - T_s) \quad . \quad . \quad . \quad (1)$$

where h is the surface heat transfer coefficient; the remaining quantities are defined in the Notation. This equation is true only if the temperature gradients through the skin thickness are small, as in the case of high conductivity (metallic) thin skins. The surface heat transfer coefficient is usually calculated from

$$h = \mathrm{St}\, c_p \rho_a V \quad . \quad . \quad . \quad (2)$$

where the Stanton number St depends on Reynolds and Mach numbers and temperature, the density ρ_a depends on altitude, the specific heat of air at constant pressure c_p is a function of temperature and the velocity V depends on the flight history of the aircraft. If the aircraft is suddenly accelerated in level flight from a steady cruising speed to a high Mach number, then the surface heat transfer coefficient h can be treated as a constant with sufficient accuracy for engineering purposes.

Solving equation (1) for constant value of h

$$T_s - T_i = (T_{ad} - T_i)(1 - e^{-\beta t})$$

or $$T_1 = T_0(1 - e^{-\beta t}) \quad . \quad . \quad . \quad (3)$$

where $$\beta = h/(\rho_1 c_1 d_1) \quad . \quad . \quad . \quad (4)$$

and T_0 is the temperature difference between the adiabatic wall temperature and the initial temperature of the skin.

3. Transient Temperature Distribution in Circular Bulkheads

Consider a circular cylindrical shell of radius R_0 stiffened by a bulkhead and subjected to aerodynamic heating. It is assumed that the skin temperature does not vary along the length of the shell and is given by equation (3), and that the heat transfer by radiation and convection of the air trapped within the structure is negligible.

The heat loss through the bulkhead diaphragm by means of conduction along the skin is also neglected. Similar assumption is usually made when analysing temperature distribution in skin/web combinations. Analysis without this restriction can be developed, but the complexity of the resulting expressions for temperature and stress distributions would not justify the additional accuracy.[2]

If rivets or bolts are used to join the bulkhead and the fuselage skin, thermal contact is not perfect and a temperature jump occurs across the interface between the two parts, which would influence the temperature distribution in the bulkhead. Mathematically, this is equivalent to a discontinuity in the temperature distribution.

The differential equation for the heat flow in the bulkhead diaphragm is

$$\frac{\partial^2 T_2}{\partial r^2} + \frac{1}{r}\frac{\partial T_2}{\partial r} - \frac{1}{\kappa_2}\frac{\partial T}{\partial t} = 0; \quad 0 \leqslant r \leqslant R_0; \quad t > 0. \quad (5)$$

The boundary condition at the bulkhead/skin joint is

$$K_2 \frac{\partial T_2}{\partial r} = H_j \Delta T; \quad \Delta T = T_1 - T_2; \quad r = R_0 \quad (6)$$

where H_j is the thermal conductance of the joint, ΔT the temperature drop across the interface, and K_2 the thermal conductivity of the bulkhead material. Substituting equation (3) into (6)

$$\frac{\partial T_2}{\partial r} = \frac{H_j}{K_2}\{T_0(1 - e^{-\beta t}) - T_2\}; \quad r = R_0. \quad (7)$$

The remaining boundary and initial conditions are

$$\frac{\partial T_2}{\partial r} = 0; \quad r = 0 \quad . \quad . \quad . \quad (8)$$

$$T_2 = 0; \quad t = 0, \quad . \quad . \quad (9)$$

The general solution of equation (5) with the boundary and initial conditions (7), (8) and (9) can be obtained by the Laplace transformation method.[4] Using this method it can be shown that the radial distribution of temperature in the bulkhead diaphragm becomes

$$T_2 = T_0 \left\{ 1 - \frac{J_0(\mu r/R_0)\, e^{-\mu^2 N}}{[J_0(\mu) - \theta\mu J_1(\mu)]} - 2 \sum_j \frac{J_1(w_j R_0)\, J_0(w_j r)\, e^{-w_j^2 R_0^2 N}}{w_j R_0 (1 - w_j^2 R_0^2/\mu^2)\,[J_0^2(w_j R_0) + J_1^2(w_j R_0)]} \right\} \quad . \quad . \quad . \quad (10)$$

where three non-dimensional parameters have been introduced, time parameter $N = \kappa_2 t/R_0^2$, heating parameter $\mu^2 = \beta R_0^2/\kappa_2$ and relative thermal resistance $\theta = K_2/(H_1 R_0)$. The values of $w_j R_0$ are determined from the roots of

$$J_0(w_j R_0) - \theta w_j R_0 J_1(w_j R_0) = 0 \quad . \quad (11)$$

The roots of this equation have been calculated in Reference 4.

Two extreme cases can be considered: (*a*) zero thermal resistance, corresponding to a thermally continuous joint, and (*b*) infinite resistance, corresponding to a perfect thermal insulation at the joint. In the first case $\theta = 0$ and the temperature distribution becomes

$$T_2 = T_0 \left\{ 1 - \frac{J_0(\mu r/R_0)\, e^{-\mu^2 N}}{J_0(\mu)} - 2 \sum_j \frac{J_0(w_j r)\, e^{-w_j^2 R_0^2 N}}{w_j R_0 (1 - w_j^2 R_0^2/\mu^2)\, J_1(w_j R_0)} \right\} . \quad (12)$$

with $$J_0(w_j R_0) = 0. \quad . \quad . \quad . \quad (13)$$

In the second case $\theta = \infty$ and equation (11) becomes $J_1(w_j R_0) = 0$, giving $T_2 = 0$, which means that the temperature of the bulkhead is not affected by the aerodynamic heating of the fuselage skin.

4. Thermal Stresses in Cylindrical Shells

The general analyses of thin isotropic axisymmetrical shells developed by Love and Meissner have been extended by Eichelberg[5] to include the temperature effects under arbitrary distribution of temperature. A shell structure stiffened by bulkheads or frames can be analysed by considering various components as separate parts and then comparing the boundary conditions on stress and/or displacement on each component. If the bulkheads or frames are sufficiently separated, it is possible to consider with sufficient accuracy the boundary conditions at each boundary independently. Thus, the number of free constants in the solution is reduced, as for each edge only that part of the solution which decreases towards the other boundary is considered. For a cylindrical shell extending to infinity on either side of $x = 0$ and subjected to a temperature increase T_1, the stress-resultants, stress-couples and radial deflections for positive values of x are given by[6]

$$N_x = 0 \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$$N_\varphi = -\frac{\sqrt{2}}{2} P R_0 m\, e^{-mx} \sin\left(mx + \frac{\pi}{4}\right) . \quad . \quad (15)$$

$$Q = -\frac{P}{2} e^{-mx} \cos(mx) \quad . \quad . \quad . \quad . \quad (16)$$

$$M_x = -\frac{(\sqrt{2})\,P}{4m} e^{-mx} \sin\left(mx - \frac{\pi}{4}\right); \; M_\varphi = \nu_1 M_x \quad (17)$$

$$w = \frac{(\sqrt{2})\,P}{8m^3 D} e^{-mx} \sin\left(mx + \frac{\pi}{4}\right) - \alpha_1 R_0 T_1 \quad (18)$$

with $$m^4 = 3(1 - \nu_1^2)/(R_0^2 d_1^2) \quad . \quad . \quad . \quad . \quad (19)$$

and $$D = E_1 d_1^3/[12(1 - \nu_1^2)] \quad . \quad . \quad . \quad . \quad (20)$$

The unknown constant of integration P (loading reaction between the shell and bulkhead diaphragm) will be determined by comparing radial displacements of the shell and the bulkhead diaphragm. For the shell, the radial displacement w is given by, from equation (18),

$$w_{\text{shell}} = \frac{P}{8m^3 D} - \alpha_1 R_0 T_1 \quad . \quad . \quad (21)$$

while for the diaphragm[7]

$$w_{\text{bulkhead}} = -\left\{ \frac{P(1 - \nu_2) R_0}{E_2 d_2} + 2\frac{\alpha_2}{R_0} \int_0^{R_0} T_2 r\, dr \right\} \quad (22)$$

Equating equations (21) and (22) and then substituting equations (3) and (10) and integrating we have

$$P = \frac{\alpha_1 R_0 T_0 S}{\{1/(8m^3 D) + (1 - \nu_2) R_0/(E_2 d_2)\}} \quad . \quad (23)$$

where

$$S = 4\frac{\alpha_2}{\alpha_1} \sum_j \frac{e^{-w_j^2 R_0^2 N}}{w_j^2 R_0^2 (1 - w_j^2 R_0^2/\mu^2)\{1 + J_0^2(w_j R_0)/[J_1^2(w_j R_0)]\}} - \left\{ 1 - \frac{2(\alpha_2/\alpha_1) J_1(\mu)}{\mu [J_0(\mu) - \theta\mu J_1(\mu)]} \right\} e^{-\mu^2 N} + (1 - \alpha_2/\alpha_1) \quad (24)$$

and w_j's are given by the roots of equation (11). For thermally perfect joints at the fuselage skin/bulkhead joint ($\theta = 0$) the above equation simplifies to

$$S = 4\frac{\alpha_2}{\alpha_1} \sum_j \frac{e^{-w_j^2 R_0^2 N}}{w_j^2 R_0^2 (1 - w_j^2 R_0^2/\mu^2)} - \left\{ 1 - \frac{2(\alpha_2/\alpha_1) J_1(\mu)}{\mu J_0(\mu)} \right\} e^{-\mu^2 N} + (1 - \alpha_2/\alpha_1) \; . \quad (25)$$

with w_j's given by equation (13). The function S is proportional to the radial load P and hence also to the thermal stresses in the shell [*see* equations (15) to (17)]. Figs. 1 to 4 show variation of the function S with the non-dimensional time parameter N for a series of values of μ and α_2/α_1 and zero thermal resistance at the bulkhead joint ($\theta = 0$). A perusal of these graphs shows that the maximum transient stress in the shell is an increasing function of the heating parameter μ. Thus it increases with the rate of heating constant β and the radius R_0 and decreases with the increase in thermal diffusivity of the bulkhead material κ_2. The point at which the maximum thermal stress occurs (maximum S) is a delayed function of time, the delay becoming increasingly pronounced as μ is decreased. The dotted curves show variation of S for $\mu = \infty$ which gives maximum stress at $N = 0$. For any other value of μ the curves for S cross the limiting case curve and then approach it asymptotically from above. The maximum negative value of S occurs in the steady state ($N = \infty$) when $S = 1 - \alpha_2/\alpha_1$ and $\alpha_2/\alpha_1 > 1{\cdot}0$. In Fig. 5 the maximum positive value of S is plotted against the heating parameter μ for various values of α_2/α_1 and $\theta = 0$. This indicates that if dissimilar materials are

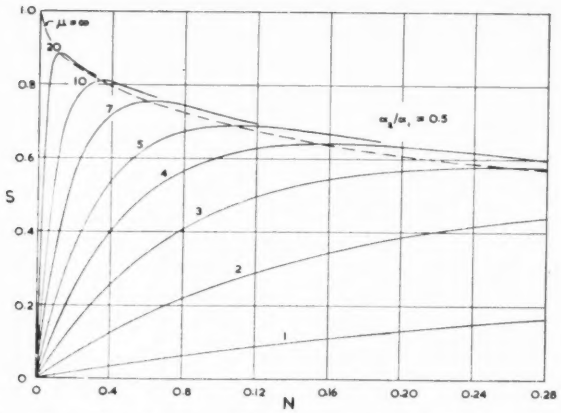

FIGURE 1. Variation of S with non-dimensional time parameter N for $\alpha_2/\alpha_1 = 0{\cdot}5$.

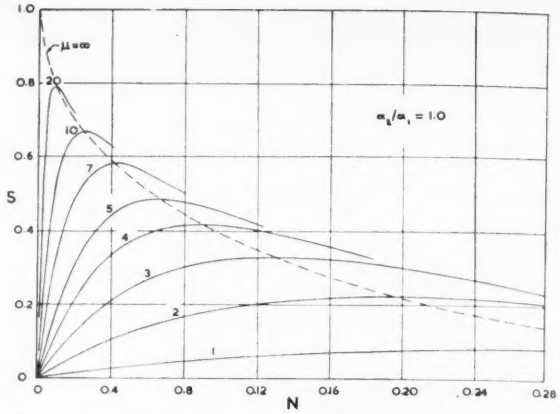

FIGURE 2. Variation of S with non-dimensional time parameter N for $\alpha_2/\alpha_1 = 1{\cdot}0$.

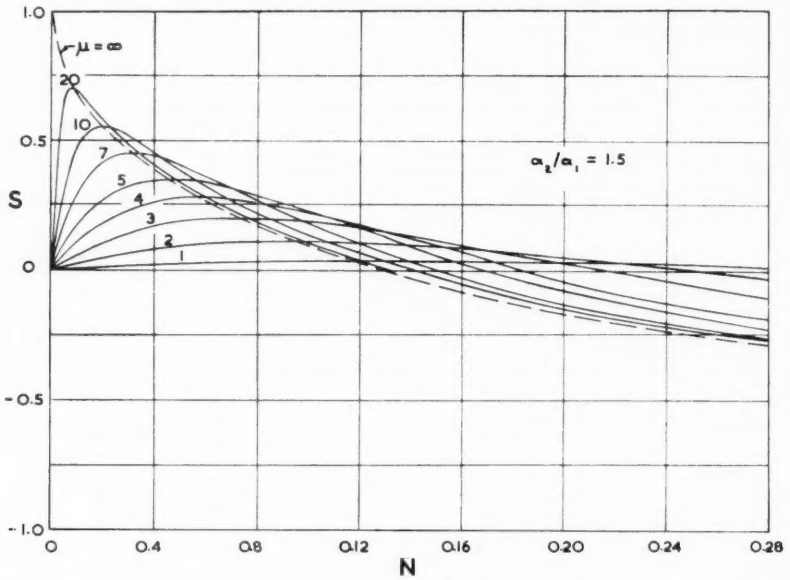

FIGURE 3. Variation of S with non-dimensional time parameter N for $\alpha_2/\alpha_1 = 1{\cdot}5$.

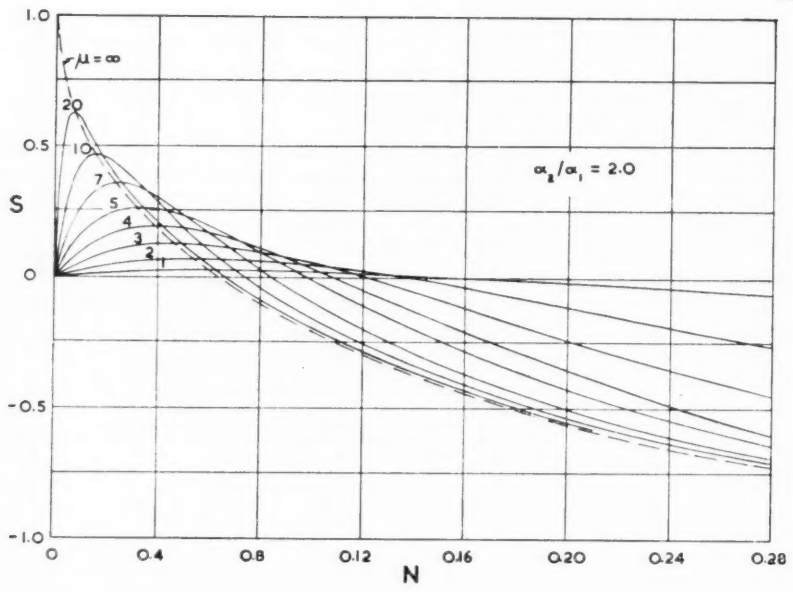

FIGURE 4. Variation of S with non-dimensional time parameter N for $\alpha_2/\alpha_1 = 2{\cdot}0$.

used, then it is advantageous to use combinations with $\alpha_2/\alpha_1 > 1$. The case of $\alpha_2/\alpha_1 = 1{\cdot}5$ in Fig. 3 corresponds, approximately, to a stainless steel skin and light alloy bulkhead configuration. Here for given values of β and R_0 the parameter μ is reduced owing to the higher thermal diffusivity of light alloy as compared with steel. This gives some reduction in the maximum stress, but on the other hand such a combination gives rise to thermal stresses in the steady state because of the difference in the coefficients of thermal expansion. Furthermore, the reduction in strength of the light alloy bulkhead diaphragm owing to the increased temperature may not be permissible.

The effect of thermal resistance on the maximum stresses is illustrated in Fig. 6. It becomes apparent that the increase in the stress is significant only for values of $\theta > > 0{\cdot}01$, especially for large values of μ. The thermal conductance, and hence thermal resistance, of structural joints can only be obtained experimentally. The available tests on aircraft joints suggest that for a typical fuselage structure with reasonably good joints the values of θ should be rather less than 0·01 and, consequently, only a very small increase in the thermal stresses can be expected.

5. Thermal Stresses in Circular Bulkhead Diaphragms

The stress distribution in a circular diaphragm subjected to arbitrary axi-symmetrical distribution of temperature is given by[7]

$$\sigma_{r1} = \alpha_2 E_2 \left\{ \frac{1}{R_0^2} \int_0^{R_0} T_2 r\, dr - \frac{1}{r^2} \int_0^{r} T_2 r\, dr \right\} . \quad (26)$$

$$\sigma_{\theta 1} = \alpha_2 E_2 \left\{ -T_2 + \frac{1}{R_0^2} \int_0^{R_0} T_2 r\, dr + \frac{1}{r^2} \int_0^{r} T_2 r\, dr \right\} . \quad (27)$$

where σ_{r1} and $\sigma_{\theta 1}$ are the radial and circumferential stresses respectively due to the temperature alone. In addition to these stresses there is a uniform stress field throughout the bulkhead diaphragm caused by the transverse shear in the shell. Substituting equation (12) into (26) and (27), integrating and adding the uniform stress (P/d_2) calculated from equations (23) and (25) the complete stress distribution in the diaphragm becomes

$$\sigma_r = \frac{\alpha_1 R_0 T_0 S}{d_2\{1/(8m^2D) + (1-\nu_2) R_0/(E_2 d_2)\}} + \alpha_2 E_2 T_0 \left\{ \left[\frac{J_1(\mu r/R_0)}{(\mu r/R_0) J_0(\mu)} - \frac{J_1(\mu)}{\mu J_0(\mu)} \right] e^{-\mu^2 N} + 2 \sum_j \frac{[J_1(w_j r)/(r/R_0) J_1(w_j R_0)] - 1}{w_j^2 R_0^2 (1 - w_j^2 R_0^2/\mu^2)} e^{-w_j^2 R_0^2 N} \right\} \quad (28)$$

$$\sigma_t = \frac{\alpha_1 R_0 T_0 S}{d_2\{1/(8m^2D) + (1-\nu_2) R_0/(E_2 d_2)\}} + \alpha_2 E_2 T_0 \left\{ \left[\frac{J_0(\mu r/R_0)}{J_0(\mu)} - \frac{J_1(\mu r/R_0)}{(\mu r/R_0) J_0(\mu)} \right] - \frac{J_1(\mu)}{\mu J_0(\mu)} e^{-\mu^2 N} + 2 \sum_j \frac{\left[\frac{w_j R_0 J_0(w_j r)}{J_1(w_j R_0)} - \frac{R_0}{r} \frac{J_1(w_j r)}{J_1(w_j R_0)} - 1 \right]}{w_j^2 R_0^2 (1 - w_j^2 R_0^2/\mu^2)} e^{-w_j^2 R_0^2 N} \right\} . \quad (29)$$

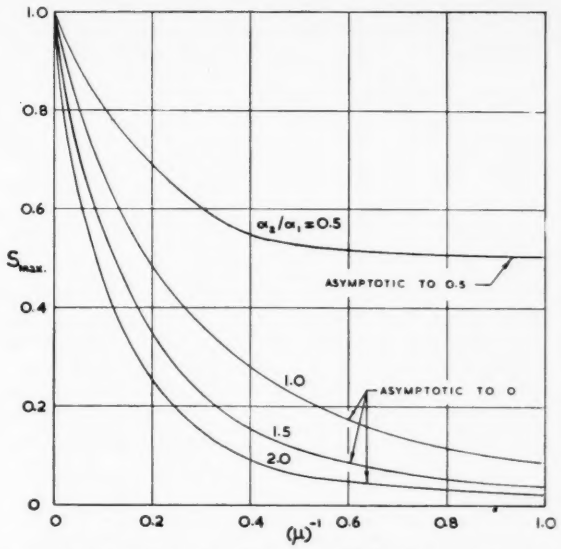

FIGURE 5. Variation of positive S_{max} with heating parameter μ.

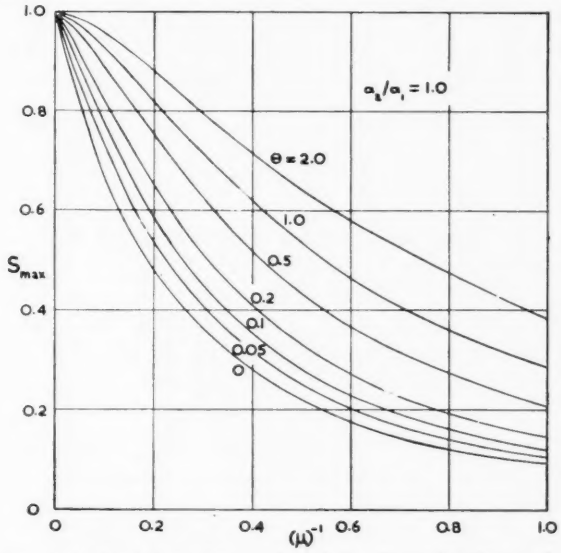

FIGURE 6. Variation of S_{max} with relative thermal resistance θ.

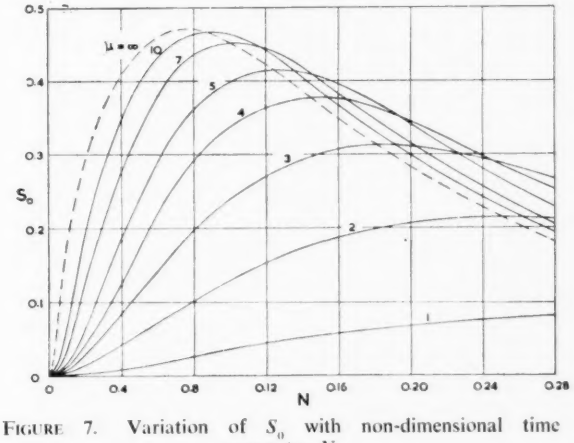

FIGURE 7. Variation of S_0 with non-dimensional time parameter N.

Substituting $r=0$ in these expressions, the stresses at the centre of the bulkhead diaphragm become

$$\sigma_r=\sigma_\theta=\frac{\alpha_1 R_0 T_0 S}{d_2\{1/(8m^3D)+(1-\nu_2)R_0/(E_2d_2)\}}+\tfrac{1}{2}\alpha_2 E_2 T_0 S_0 \quad . \quad (30)$$

where

$$S_0=\left[\frac{1}{J_0(\mu)}-\frac{2J_1(\mu)}{\mu J_0(\mu)}\right]e^{-\mu^2 N}+4\sum_j\frac{\left(\dfrac{w_jR_0}{2J_1(w_jR_0)}-1\right)e^{-w_j^2R_0^2N}}{w_j^2R_0^2(1-w_j^2R_0^2/\mu^2)} \quad . \quad (31)$$

Equation (31) is plotted in Fig. 7 as a series of curves relating S_0 to N for various values of the heating parameter μ. Comparison of Figs. 2 and 7 shows that, for a given value of μ, the peak value of S_0 occurs later than the corresponding peak value of S. Since the thermal stress at $r=0$ depends on both S and S_0, its maximum value will occur at some intermediate time between the times corresponding to the maxima of S and S_0.

6. Circular Frames

Here the solution is obtained by comparing radial displacements of the joint between the shell and the circular frame. If we assume that the mean frame temperature is T_3 then the radial displacement at the joint

$$w_3=-[R_3\alpha_3T_3+PR_3^2/(A_fE_3)]$$
$$\simeq-[R_0\alpha_3T_3+PR_0^2/(A_fE_3)] \quad . \quad (32)$$

where R_3 is the mean frame radius and A_f is the cross-sectional area of the frame. Equating equations (21) and (32) we obtain the reaction between the shell and the frame. Hence

$$P=(\alpha_1T_1-\alpha_3T_3)R_0/[1/(8m^3D)+R_0^2/(A_fE_3)] \quad (33)$$

and stresses are calculated from equations (15) to (17). The expansion difference $(\alpha_1T_1-\alpha_3T_3)R_0$ is usually small and consequently the frame restraint does not give rise to any appreciable thermal stresses.

7. Cylindrical Shell Stiffened by Stringers

The analysis developed for thin isotropic cylindrical shells is also applicable to shells with longitudinal stiffeners. Neglecting flexural rigidity in the circumferential direction and putting $D=E_1I/b$, equations (14) to (18) become

$$N_x=0 \quad . \quad (34)$$

$$N_\varphi=-\frac{\sqrt{2}}{2}PR_0n\,e^{-nx}\sin\left(nx+\frac{\pi}{4}\right) \quad . \quad (35)$$

$$Q=-\frac{P}{2}e^{-nx}\cos nx \quad . \quad (36)$$

$$M_x=-\frac{(\sqrt{2})P}{4n}e^{-nx}\sin\left(nx-\frac{\pi}{4}\right);\quad M_\varphi=0 \quad (37)$$

$$w=\frac{(\sqrt{2})Pb}{8n^3E_1I}e^{-nx}\sin\left(nx+\frac{\pi}{4}\right)-\alpha_1R_0T_1 \quad (38)$$

with $n^4=d_1b/(4R_0^2I)$. (39)

where b is the stringer pitch and I the moment of inertia of the stringer/skin combination. Equating radial displacements, as before, we can obtain an equation for the unknown reaction P. This gives

$$P=\alpha_1R_0T_0S/\{b/(8n^3IE_1)+(1-\nu_2)R_0/(E_2d_2)\} \quad . \quad (40)$$

where S is calculated from equation (24) or (25) and hence all curves plotted in Figs. 1 to 7 can be used also for calculating thermal stresses in shells with longitudinal stiffeners.

8. Effect of Joint Flexibility

In the foregoing analysis it has been tacitly assumed that the structural joint between the fuselage skin and the bulkhead is rigid. In practice, however, some inherent flexibility is always present—such as flexibility arising from the bending stiffness of the attachment—and therefore the effective restraint afforded by the bulkhead would be less pronounced with subsequent reduction in the magnitude of thermal stresses. There is some scope for the aircraft designer's ingenuity in the detail design to provide a certain amount of flexibility in order to reduce the detrimental effects of bulkhead restraint on fuselage expansion. No generalised suggestions, however, are possible and every scheme must be treated on its own merits in a particular design.

9. Conclusions

It is concluded that the presence of bulkheads rigidly attached to the fuselage shell provides restraint against the circumferential expansion of the fuselage skin and gives rise to thermal stresses both in the skin (and stiffeners) and the bulkhead diaphragm. The resulting distribution of thermal stresses in the fuselage shell is of a localised character, but nevertheless may constitute a source of structural weakness when combined with other stresses. It is thought, however, that the adverse effects of bulkhead restraint can be partially remedied by suitable detail design of the fuselage skin/bulkhead joint.

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TECHNICAL NOTES

Contributions to this Section of the JOURNAL *will be eligible for Journal Premium Awards and will normally be published within three months of being received.*

Finite Fourier Transform Analysis of the Flexure of a Non-Uniform Beam

by

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THE OBJECT of this paper is to present an analytical method of investigating the flexure of a non-uniform beam under transverse loading. A method due to Strandhagen[1] for a uniform beam is extended to the case of a non-uniform beam, the deflection appearing in the form of a Fourier series, the coefficients of which are functions of the loading, the end-conditions, and parameters which define the non-uniform flexural rigidity of the beam.

THE TRANSFORM ANALYSIS

The finite Fourier sine and cosine transforms are defined by Sneddon[2]. If $y(x)$ satisfies the usual Dirichlet conditions in the range $(0, L)$, and its sine transform in that range is*

$$Y_s(n) = \int_0^L y(x) \sin \frac{n\pi x}{L}\, dx,$$

then at points of $(0, L)$ where $y(x)$ is continuous

$$y(x) = \frac{2}{L} \sum_{n=1}^{\infty} Y_s(n) \sin \frac{n\pi x}{L} \quad . \quad . \quad (1)$$

Also for the same $y(x)$, if the finite cosine transform is

$$Y_c(n) = \int_0^L y(x) \cos \frac{n\pi x}{L}\, dx,$$

then at points of $(0, L)$ where $y(x)$ is continuous

$$y(x) = \frac{1}{L} Y_c(0) + \frac{2}{L} \sum_{n=1}^{\infty} Y_c(n) \cos \frac{n\pi x}{L} \quad . \quad (2)$$

The x-axis is taken along the undistorted position of the beam, extending from $x=0$ to $x=L$, and y is measured vertically downwards, so that without loss in generality $y(0)=0$. The bending moment $m(x)$ at distance x from the end $x=0$ is given by $d^2y/dx^2 = f(x)$, where $f(x) = m(x)\, B(x)$. For convenience the variable flexural rigidity of the beam has been represented by $B^{-1}(x)$.

If $z(x)$ is the contribution to the bending moment at station x due to the loading in the section (x, L), then in general

$$m(x) = z(x) - R(L-x) + G, \quad . \quad . \quad (3)$$

where R is the shear force, and G the couple, exerted at $x=L$. Hence for a given loading, R and G can be deduced by imposing the end-conditions of the beam.

In the theory which follows integrals occur of the type

$$I_n = \frac{1}{2L} \int_0^L (L-x)^n f(x)\, dx, \quad . \quad . \quad (4)$$

and in particular using the bending moment equation it follows that $2LI_0 = y'(L) - y'(0)$, and $2LI_1 = y(L) - Ly'(0)$.

(*i*) *The Sine Series Representation*

The finite Fourier sine transform of the second derivative d^2y/dx^2 is determined in terms of the corresponding transform of $y(x)$ by integration by parts[2]. Hence the transform of the bending moment equation, on rearrangement, leads to the result

$$Y_s(n) = \frac{I_c}{n\pi}(-1)^{n+1} y(L) - \frac{L^2}{n^2\pi^2} F_s(n). \quad (5)$$

From the table of finite sine transforms[2], the inverse of equation (5) becomes

$$y(x) = \frac{x}{L} y(L) + S(x), \quad . \quad . \quad . \quad . \quad (6)$$

where

$$S(x) = -\frac{2L}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{n^2} \sin \frac{n\pi x}{L} \int_0^L f(u) \sin \frac{n\pi u}{L}\, du. \quad (7)$$

(*ii*) *The Cosine Series Representation*

An integration by parts of the finite Fourier cosine transform of d^2y/dx^2 enables it to be deduced in terms of the cosine transform of $y(x)$[2]. The corresponding transform of the bending moment equation then leads to

$$Y_c(n) = \frac{L^2}{n^2\pi^2} \{(-1)^n y'(L) - y'(0)\} - \frac{L^2}{n^2\pi^2} F_c(n). \quad (8)$$

From the table of finite cosine transforms[2], the inverse of equation (8) is given by

$$y(x) = \frac{1}{L} Y_c(0) + \frac{1}{6L}(3x^2 - L^2)\, y'(L) - \frac{1}{6L}\{3(L-x)^2 - L^2\}\, y'(0) + C(x), \quad (9)$$

where $Y_c(0)$ is a constant, and

$$C(x) = -\frac{2L}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{n^2} \cos \frac{n\pi x}{L} \int_0^L f(u) \cos \frac{n\pi u}{L}\, du. \quad (10)$$

Now $C(0)$ involves a term by term integration of a uniformly convergent series, hence the order of summation and

*Capital letters with appropriate subscripts indicate finite Fourier transforms.

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integration can be changed, leading to $C(0)=\frac{1}{3}L^2I_0-I_2$. With $x=0$ in equation (9), it can be shown that $2Y_c(0)=L^2y'(0)+2LI_2$, and one form of the cosine representation is therefore

$$y(x)=\frac{x}{L}y(L)+\tfrac{1}{3}(3x^2-L^2)I_0-2xI_1+I_2+C(x). \quad (11)$$

EXAMPLES

(*i*) A beam is subdivided at points $x=x_m$, $(m=1, 2, \ldots s)$, the flexural rigidity being sectionally uniform with discontinuities at these points. If $x_0=0$, then $B(x)=B_0$, a constant, in the section (x_0, x_1). Also if $B(x)$ increases by B_m, a constant, as x passes through the value x_m, then by definition

$$B(x)=\sum_{x_m<x} B_m, \qquad (m=0, 1, 2, \ldots s).$$

It will be assumed that the beam is freely hinged at both ends so that $y=y''=0$ at $x=0, L$. Since $G=0$, and $z(L)=0$, then $RL=z(0)$ in equation (3).

It will also be assumed that the beam is uniformly loaded, so that the loading function $w(x)=w$, a constant. Then $z(x)=w(L-x)^2/2$, and thus $m(x)=wx(x-L)/2$.

With this form of $m(x)$ the sine representation is given by equation (6) as $y(x)=S(x)$. The integral part of $S(x)$ can be written as

$$\tfrac{1}{2}w\sum_{x_m<L} B_m\int_{x_m}^{L} u(u-L)\sin\frac{n\pi u}{L}\,du,$$

and this is readily integrated, giving

$$y(x)=\sum_{n=1}^{\infty} b_n\sin\frac{n\pi x}{L},$$

where

$$b_n=\frac{wL^2}{n^3\pi^3}\sum_{x_m<L} B_m\left\{(L-x_m)x_m\cos\frac{n\pi x_m}{L}-\right.$$

$$\left.-\frac{L}{n\pi}(L-2x_m)\sin\frac{n\pi x_m}{L}+\frac{2L^2}{n^2\pi^2}\left(\cos\frac{n\pi x_m}{L}-\cos n\pi\right)\right. \quad (12)$$

Since $x_0=0$, the summation is equivalent to that from $m=0$ to $m=s$.

When there is complete symmetry about the mid-point of the beam, equation (12) modifies so that b_n is non-zero only for n odd. This result is applicable to reinforced girders, and for $s=1$ the result of Hetényi[3] can be reproduced.

(*ii*) A beam has three sections, subdivisions occurring at $x_1=(L-c)/2$, $x_2=(L+c)/2$, with $x_0=0$, $x_3=L$. The flexural rigidity in (x_1, x_2) is one-half of that in the other sections, hence in the notation of example (*i*), $B_0=B_1=-B_2=B$, a constant. The loading is due to two symmetrically located point loads P acting at $x=X_1=L/4$, and $x=X_2=3L/4$, hence

$$z(x)=P\sum_{X_r<x}(X_r-x), \qquad (r=1, 2) \quad . \quad (13)$$

The beam is assumed to be clamped horizontally at both ends, so that $y=y'=0$ at $x=0, L$. It follows that $I_0=I_1=0$, and these provide two equations which taken with equation (13) give the values of R and G in equation (3). In this case $R=P$, and $G=LP(3L+4c)/[16(L+c)]$. The cosine representation is given by equation (11) with $y(L)=I_0=I_1=0$, and takes the form

$$y(x)=a_0+\sum_{n=1}^{\infty} a_n\cos\frac{2n\pi x}{L},$$

where $a_0=PLB(9L^2+8Lc-8c^2)/3072$, and

$$a_n=\frac{L^4PB(-1)^n}{32_n{}^3\pi^3(L+c)}\sin\frac{n\pi c}{L}-\frac{L^3PB}{4n^4\pi^4}\left(1-\cos n\pi\cos\frac{n\pi}{2}\right).$$

Such results have application to notched beams.

CONCLUSIONS

The above analysis determines the beam deflection in terms of a Fourier series the coefficients of which can be determined immediately for any given end-conditions, loading and flexural rigidity variations. It has an advantage over the Laplace transform method[4, 5], in most cases, since this latter method, as for the Macauley analysis[6], requires extra terms to be evaluated in each section of the beam, and the application in general is more complex. The method of Hetényi[3], for determining the effect of non-uniformity of flexural rigidity, by use of a modified loading and application of results due to Timoshenko[7], does not lead to an obvious generalisation. The finite Fourier analysis leads to the same result directly and is amenable to immediate generalisation.

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On Obtaining the Shear Stress-Strain Relationship from a Hollow Specimen in Torsion

by

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A METHOD is given whereby the shear stress-strain relationship of a material can be obtained from observations made during a torsion test on a hollow circular specimen. An examination is then made of the corrections necessary when using thin-walled specimens, and some advantageous definitions of the mean diameter of a tube are suggested.

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INTRODUCTION

The use of torsion tests to obtain shear stress-strain relationships is now well established and takes one of two forms. A thin circular tube can be used, it being assumed that the stress distribution is uniform across the wall thickness, or a solid circular bar can be used, the results being analysed by a method ascribed to Nadai[1]. Swift[2] has shown that these two methods give comparable results for moderate strains.

It is now proposed to examine the case of torsion of hollow circular specimens, and especially to comment on the torsion of thin-walled tubes. In this way the errors involved in the torsion of a tubular specimen can be assessed, and new definitions of the tube mean diameter can be found which will reduce these errors.

TORSION OF A TUBE

While the behaviour of torsion specimens subject to large strains is not completely understood, for moderate strains of a circular specimen the simple torsion theory holds, there being no warping and the shear stress contours being concentric circles. Hence, if the ends of a specimen of length L are rotated through an angle θ relative to each other, then the shear strain γ at a radius r is given by

$$\gamma = r\theta/L \qquad . \quad . \quad . \quad (1)$$

If τ is the shear stress corresponding to a strain γ, then for a hollow specimen, inner radius a, outer radius b, the torque T is

$$T = \int_a^b 2\pi\tau r^2 dr$$

or, substituting the variable γ for r from equation (1),

$$T = 2\pi\,(L/\theta)^3 \int_{\gamma_a}^{\gamma_b} \tau\,(\gamma)\,\gamma^2 d\gamma. \qquad . \quad . \quad (2)$$

Noting that the limits of the integral in this equation are both functions of θ, differentiation with respect to θ gives

$$\frac{1}{2\pi L^3}\frac{d}{d\theta}(T\theta^3) = \tau\,(\gamma_b)\,{\gamma_b}^2\frac{d\gamma_b}{d\theta} - \tau\,(\gamma_a)\,{\gamma_a}^2\frac{d\gamma_a}{d\theta}.$$

Using equation (1) this becomes

$$\frac{1}{2\pi}\left(\theta\frac{dT}{d\theta} + 3T\right) = b^3\tau\,(\gamma_b) - a^3\tau\,(a\gamma_b/b) \qquad . \quad (3)$$

When a is zero, equation (3) is that given by Nadai.

In using this method it would seem that a non-zero value of τ must be given initially, but this difficulty is overcome in the initial linear portion of the curve where,

$$\tau\,(a\gamma_b/b) = (a/b)\,\tau\,(\gamma_b).$$

Where numerical differentiation is to be used the accuracy of the initial part of the curve can be improved by a suggestion due to Hill[3], rewriting the left hand side as

$$\frac{1}{2\pi}\left(\theta\frac{dT}{d\theta} + 3T\right) = \frac{1}{2\pi}\left\{\theta^2\frac{d}{d\theta}\left(\frac{T}{\theta}\right) + 4T\right\}.$$

In the linear portion of the curve the derivative is zero, and is only small when the rate of work-hardening is large.

Now, considering a tube of not too great a wall thickness and having some mean radius c, then it is possible to expand equation (3) as

$$\begin{aligned}\frac{1}{2\pi}\left(\theta\frac{dT}{d\theta} + 3T\right) &= b^3\left\{\tau + (b-c)\frac{d\tau}{dr} + \tfrac{1}{2}(b-c)^2\frac{d^2\tau}{dr^2} + \ldots\right\} - \\ &\quad - a^3\left\{\tau - (c-a)\frac{d\tau}{dr} + \tfrac{1}{2}(c-a)^2\frac{d^2\tau}{dr^2} - \ldots\right\} \\ &= \tau\,(b^3 - a^3) + \frac{d\tau}{dr}\left\{b^3\,(b-c) + a^3\,(c-a)\right\} + \\ &\quad + \tfrac{1}{2}\frac{d^2\tau}{dr^2}\left\{b^3\,(b-c)^2 - a^3\,(c-a)^2\right\} \qquad (4)\end{aligned}$$

τ now represents the stress at the radius c, the derivatives also having their value at this radius.

From equation (1),

$$\left(\frac{d\tau}{dr}\right)_c = \frac{\theta}{c}\frac{d\tau}{d\theta}$$

and as a first approximation to the stress

$$\tau \simeq 3T/[2\pi\,(b^3 - a^3)]$$

so that

$$\left(\frac{d\tau}{dr}\right)_c \simeq \frac{3\theta}{2\pi c\,(b^3 - a^3)}\frac{dT}{d\theta}; \qquad . \quad (5)$$

thus, equation (4) becomes

$$\begin{aligned}\theta\frac{dT}{d\theta} + 3T &= 2\pi\tau\,(b^3 - a^3) + \frac{3}{(b^3 - a^3)}\left\{b^3\,(b-c) + \right. \\ &\quad \left. + a^3\,(c-a)\right\}\frac{\theta}{c}\frac{dT}{d\theta} + \\ &\quad + \frac{3}{2\,(b^3 - a^3)}\left\{b^3\,(b-c)^2 - a^3\,(c-a)^2\right\}\frac{\theta^2}{c^2}\frac{d^2T}{d\theta^2} \qquad (6)\end{aligned}$$

Suppose now that c is taken as the arithmetic mean radius $(a+b)/2$, then

$$\begin{aligned}\frac{2\pi}{3}(b^3 - a^3)\,\tau\,(\gamma_c) &= T - \left\{\frac{(b-a)\,(b^3 + a^3)}{(b+a)\,(b^3 - a^3)} - \frac{1}{3}\right\}\theta\frac{dT}{d\theta} - \\ &\quad - \frac{1}{2}\left(\frac{b-a}{b+a}\right)^2\theta^2\frac{d^2T}{d\theta^2} \qquad . \quad (7)\end{aligned}$$

With this definition of mean radius for a tube of outside diameter/wall thickness ratio of 10:1 the first correction term can exceed 3 per cent for a material with a high rate of work-hardening when $\theta dT/d\theta$ can be of the same magnitude as T. The coefficient of the second term is only 0·0062, but this could be quite important if the material has a stress-strain curve with a sharp knee. Consequently, use of the arithmetic mean radius entails correction terms in deriving the stress-strain curve unless the diameter/thickness ratio is greater than, say, 15-20:1.

An alternative definition can be found for the mean radius by choosing c such that the coefficient of $\theta dT/d\theta$ is zero. Then, from equation (6)

$$1 = 3\left\{b^3\,(b-c) + a^3\,(c-a)\right\}/\left\{c\,(b^3 - a^3)\right\}$$

or

$$c = \frac{3\,(b^4 - a^4)}{4\,(b^3 - a^3)} \qquad . \quad . \quad . \quad (8)$$

This expression for mean radius is similar to a result given by Wooley[4], and,

$$\frac{2\pi}{3}(b^3 - a^3)\,\tau\,(\gamma_c) = T - \frac{1}{18}\left\{\frac{16\,(b^5 - a^5)\,(b^3 - a^3)}{(b^4 - a^4)^2} - 15\right\}\theta^2\frac{d^2T}{d\theta^2} \qquad . \quad . \quad . \quad (9)$$

Again, for a tube with an outside diameter/thickness ratio of 10:1 the mean diameter/thickness ratio is 9·074:1 as compared with 9:1 in the previous case. The coefficient of the correction term is now only 0·0033 as compared with 0·0062 previously, so that by changing the definition of the mean radius the accuracy of the curve is enhanced.

However, for ease in deriving the stress-strain curve it is most convenient to retain the construction suggested by Nadai, and to eliminate the $\theta^2 d^2T/d\theta^2$ term. Thus, from equation (6)

$$(b^5 - a^5) - 2c\,(b^4 - a^4) + c^2\,(b^3 - a^3) = 0$$

or, taking the negative root of this quadratic

$$c = \{(b^4 - a^4) - (b - a)\sqrt{(ab)^3}\}/(b^3 - a^3), \quad . \qquad (10)$$

the stress is then given by

$$\frac{2\pi}{3}(b^3 - a^3)\,\tau(\gamma_c) = T - \left\{\frac{(b^4 - a^4)}{(b^4 - a^4) - (b - a)\sqrt{(ab)^3}} - \frac{4}{3}\right\}\theta\frac{dT}{d\theta} \qquad (11)$$

For the 10:1 tube considered previously the mean diameter/thickness ratio is 9·166:1 and the coefficient of $\theta dT/d\theta$ is only 0·0134, this representing the maximum possible correction. Thus, with c defined by equation (10) it is possible to use a tube of outside diameter thickness ratio of 10:1, and know that the torque-twist and shear stress-strain curves are identical (apart from scale) to an accuracy of about one per cent or better.

SUMMARY

The relationships between the shear stress-strain curve and torque-twist curve of a tube are examined and it is shown that inaccuracies can be reduced by suitable choice of the mean diameter.

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A New Method for the Solution of a Differential Equation with Two-Point Boundary Conditions Applied to the Compressible Boundary Layer on a Yawed Infinite Wing

by

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and

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THE COMPRESSIBLE laminar boundary layer on a yawed infinite wing is considered in Ref. 1, where it is shown that the problem may be solved by a direct solution of the linearised equations of motion under certain assumptions. As an example of this procedure the boundary layer near a stagnation point was calculated. Tinkler[2] has published solutions of the exact equations for the general Falkner-Skan case (Ref. 1) obtained on the M.I.T. differential analyser for several values of the parameter involved. It has been found that the numerical results of Ref. 1 were in error and the corrected results obtained by a new method are tabulated below. Tinkler's exact solution of the stagnation point flow for $\omega = 0{\cdot}10$ is also given for comparison, and it will be seen that there is close agreement.

The differential equations of motion for this case are:—

$$f''' - f'^2 + ff'' = -(1 + \omega\,(1 - g^2)) \quad . \qquad (1)$$

with $f(0) = f'(0) = 0,\ f'(\infty) = 1$

and

$$g'' + fg' = 0 \quad . \quad . \qquad (2)$$

with $g(0) = 0,\ g(\infty) = 1.$

After expanding the chordwise flow function $f(\eta)$ and the spanwise flow function $g(\eta)$ in series of powers of ω;

$$f = f_1 + \omega f_2 + \quad . \quad . \quad . \qquad (3)$$

$$g = g_1 + \omega g_2 + \quad . \quad . \quad . \qquad (4)$$

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f_1 is found to satisfy the equation

$$f_1'^2 - f_1 f_1'' = 1 + f_1''' \quad . \quad . \quad . \qquad (5)$$

i.e. f_1 is the chordwise flow function for the incompressible case; the solution of equation (5) has been tabulated by Howarth.

The equation for f_2 is

$$2f_1' f_2' - f_1 f_2'' - f_2 f_1'' - f_2''' = 1 - g_1^2 \quad . \qquad (6)$$

Now the equation for g_1 is

$$g_1'' + f_1 g_1' = 0 \quad . \quad . \quad . \qquad (7)$$

and the solution has been tabulated by Cooke. The method of solving equation (6) was suggested by E. J. York of Mathematical Services Department, R.A.E., and is thought to be of some interest. It will therefore be explained in more detail.

Using a Lagrangian interpolation formula we have

$$f_2(x) = \sum_{j=0}^{N} L_j(x)\,f_2(x_j)$$

where

$$L_j(x) = \prod_{\substack{i=0 \\ i \neq j}}^{N} \frac{(x - x_i)}{(x_j - x_i)}$$

Differentiating,

$$f_2^{(n)}(x) = \sum_{j=0}^{N} L_j^{(n)}(x)\,f_2(x_j)$$

equation (6) becomes

$$2f_1'(x)\sum_{j=0}^{N} L_j^{(1)}(x)\,f_2(x_j) - f_1(x)\sum_{j=0}^{N} L_j^{(2)}(x)\,f_2(x_j) -$$

$$- f_1''(x)\sum_{j=0}^{N} L_j(x)\,f_2(x_j) - \sum_{j=0}^{N} L_j^{(3)}(x)\,f_2(x_j) = 1 - g_1^{\,2}(x) \quad (8)$$

The values of f_1, f_1', f_1'' and g_1 are known at equally spaced intervals $x = 0\,(0{\cdot}2)\,4{\cdot}6$ and we may take $x = 4{\cdot}6$ as infinity.

We write $x_s = (s-1)\,0{\cdot}2$ where $s = 1\,(1)\,24$.

Using a sixth degree polynomial, the Lagrangian coefficients are easily evaluated and used to build up "differentiating matrices" A_r $(r = 1, 2, 3)$ with elements

$$a_{ij} = \begin{cases} L_{j-i+3}^{(r)}(3) & 4 \leqslant i \leqslant 24 \\ L_{j-1}^{(r)}(2) & i = 3 \\ L_{j-21}^{(r)}(i-21) & i = 25, 26 \end{cases}$$

The other three rows $(i = 1, 2, 27)$ are given by the boundary conditions:—

$$f_2(0) = 0$$

$$f_2'(0) = 0 \text{ becomes } \sum_{s=-1}^{5} L_{s+1}^{(1)}(2)\,f_2(s) = 0$$

$$f_2'(\infty) = 0 \text{ becomes } \sum_{s=19}^{25} L_{s-19}^{(1)}(5)\,f_2(s) = 0.$$

Unspecified elements are zero.

Equation (8) becomes a set of linear equations:—

$$(2\underline{f_1'}A_1 - \underline{f_1}A_2 - \underline{f_1''}I - A_3)\underline{f_2} = \underline{1 - g_1^{\,2}}$$

where the diagonal matrices $\underline{f_1}$, $\underline{f_1'}$, $\underline{f_1''}$ and the vector $\underline{1 - g_1^{\,2}}$ are extended by zeros or ones as appropriate to the boundary conditions.

The operations of matrix multiplication and subtraction and the solution of the equations were carried out on Pilot A.C.E. at the National Physical Laboratory. The work was checked by repeating the process taking the interval of x as 0·4.

The method is now being generalised for any linear differential equations of whatever order with two-point boundary conditions.

Stagnation point flow with $\omega = 0{\cdot}10$

$f'(n)$ = chordwise velocity function

$g(n)$ = spanwise velocity function.

			Linearised Solution	*Exact Solution*	
n	f_2	f_2'	$f' = f_1' + \omega f_2'$	f'	g
0	0	0	0	0	0
0·4	0·0429	0·1883	0·4332	0·4333	0·2306
0·8	0·1333	0·2440	0·7103	0·7101	0·4518
1·2	0·2268	0·2140	0·8681	0·8677	0·6457
1·6	0·2996	0·1493	0·9473	0·9468	0·7958
2·0	0·3461	0·0865	0·9819	0·9814	0·8964
2·4	0·3710	0·0425	0·9948	0·9943	0·9544
2·8	0·3825	0·0177	0·9989	0·9984	0·9829
3·2	0·3869	0·0062	0·9998	0·9992	0·9949
3·6	0·3884	0·0018	0·9999	0·9992	0·9994
4·0	0·3888	0·0004	1·0000	0·9991	1·0006
4·4	0·3889	0	1·0000	0·9989	1·0010
4·8	0·3890	0	1·0000	1·0000	1·0000

N.B.—Since the linearised solution for f' is so close to the exact solution, the linearised solution for g will be almost identical with the exact solution (it is an integral involving the chordwise function, as shown in Ref. 1). The solution for g has not therefore been recalculated, and only Tinkler's values are quoted.

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Rotary Stability Derivatives from Distorted Models (September 1956)

CORRESPONDENCE

WITH reference to the Technical Note on Rotary Stability Derivatives from Distorted Models by D. J. Foster and G. W. Haynes, in the September 1956 Journal (p. 623), the use of distorted models for determination of rotary stability derivatives was described in the Soviet book "Nekotorie zadaci i metodi experimentalnoj aerodinamiky" by S. G. Popov (Some problems and methods of experimental aerodynamics.—Moskva 1952).

In this book Popov also says that Mr. G. A. Gurzenko used this method for an airship model and that the results of wind tunnel tests and full-scale tests were in good agreement. Mr. Gurzenko's Report was published in "Trudi CAGI," No. 132, 1934.

PROFESSOR ING. DR. RUDOLF PESEK
Technical University, Prague.

WE were very interested to hear from Dr. Pesek of the prior existence of the method of obtaining rotary stability derivatives from distorted models. Unfortunately we have been unable to obtain the references which he quotes, but we were pleased to hear that the method had been actually used, and gave results which agreed with full-scale tests.

D. FOSTER and G. HAYNES.

Graduates' and Students' Section

Nuclear Power for Aircraft

ON Tuesday 30th October the Graduates' and Students' Section was given a most fascinating glimpse into the possible future when Mr. E. P. Hawthorne, B.A., A.F.R.Ae.S., Chief Executive of Hawker Siddeley Nucleonics Ltd., lectured on "Nuclear Power for Aircraft."

After describing briefly the thermal and fast type of reactors, Mr. Hawthorne plumped for the latter as a possible type for an aircraft power plant. Although it required a large proportion of the very expensive fissile U235, its small bulk enabled it to be fitted to an aircraft of practical size. With this type of reactor it was necessary to extract the enormous amount of heat energy generated from a relatively small surface area, so that some form of liquid metal was needed as a heat exchange medium. The sodium passed through the pile became radioactive so it was necessary to have a secondary heat exchange to another sodium circuit to avoid circulating the active sodium outside the shielded area.

The major problem of a nuclear-powered aircraft was the provision of adequate shielding. The radiations emitted by the reactor consisted among others of gamma particles which were absorbed by a high mass material and neutron capture which needed a material of relatively low mass. The shielding material, therefore, might consist of a very thick layer of lead immediately next to the reactor, with further layers of boron or lithium (for neutron capture) interspersed with iron. It was possible to "cheat a little" on weight by shielding only the part of the reactor opposite the cockpit or, alternatively, by shielding the cockpit instead of the reactor.

Mr. Hawthorne then showed a slide of a possible atomic aircraft. This was an aircraft with a long slender fuselage and an aspect ratio of about 2 with a "gas turbine" on each wing tip. A fast reactor was located in the centre section from which a secondary sodium circuit ran through each wing to a flat plate heat exchanger in each "turbo-jet." This aircraft would weigh between 150,000 lb. and 300,000 lb. and should have a payload of approximately 10,000 lb. The design performance was a Mach number of 2·5 at 60,000 ft. which required a 335,000 h.p. reactor. The reactor core would be 20 in. diameter and would have a rating of 67,000 h.p./cubic feet core; the outlet temperature of the sodium would be 750°C. The reactor would weigh between 30,000 lb. and 35,000 lb. and the heat exchanger units, which were located between the compressor and turbine of the "turbo-jets," 1,000 lb. per 1,000 lb. thrust.

Among the many problems of such an aircraft were:—

(*i*) The difficulty of obtaining the higher take-off thrust from a reactor designed for cruising flight.

(*ii*) The dangers of loss of control of the reactor which would vaporise the liquids and solids it contained and discharge them to atmosphere with extreme risk to the surrounding population.

(*iii*) The dangers of a crash and subsequent rupture of the reactor, which would contaminate the crash area with highly radioactive fission products which might take six months to a year to decay to a safe level.

(*iv*) The high residual energy level, 6 per cent, which a reactor retained immediately after being shut down, which would make even a crash tight fail safe reactor a fairly serious danger if a crash occurred while it was operating at take-off power.

These risks would have to be completely eliminated before it would be possible to operate atomic-powered aircraft. One suggested way of avoiding these risks was to use remote controlled atomic-powered aircraft as tugs for conventionally powered aircraft. These tugs would normally remain at high altitude, the towed aircraft joining and leaving the tug near the departure and destination airfields.

Mr. Hawthorne concluded that the advantage of the atomic-powered aircraft was unlimited range and endurance. If such an aircraft were required he thought that the Industry could build it. He then showed a film of the construction of Calder Hall power station, remarking that the power of this large and "difficult" piece of engineering was only one-third of the aircraft which he had proposed in his paper.

Some points raised in the discussion were:—

The design and construction effort required for an atomic aircraft was so large that only one design could be built by the British Industry and that might have to be a co-operative effort.

Safety aspects appeared to preclude the early use of civil atomic aircraft. Firstly, the crash case might contaminate an international airport and close it down for many months. Secondly, civil aircraft would require heavier shielding, since the total radiation from all causes which a civil passenger might experience in his life could not be carefully controlled as in a specially selected military crew, who could, therefore, suffer "high" short term radioactivity dosages. The radioactivity level in the aircraft would not be sufficient to reduce the structural strength. Rapid throttle response characteristics might require the constant generation of excess heat in conjunction with a heat dump which is cut off when the throttle is opened quickly. Atomic aircraft economics might be better than those of kerosine-powered aircraft.—P. A. H.

Farnborough Visited

VISITS, I find, fall into two groups. There are those in which a lot of time is taken seeing what is, on reflection afterwards, very little—and there are those during which there is so much to be seen that one can take in only the highlights. Farnborough falls definitely into the latter category. A week, surely, would be necessary to take in all that can be broadly surveyed in one day—and this make no allowance for the many parts of the R.A.E. to which security bars access.

What was crammed into the one eventful day members of the Section spent there recently? In a nutshell, visits to the transonic, supersonic and hypersonic tunnels and the kinetic heating laboratory, a talk about the work of the establishment, a film describing the Comet investigation, visits to the metallurgy department, the main structures laboratory and the Comet and Britannia fatigue-test tanks. As well as this abundance of interest, time for lunch and tea in both morning and afternoon was packed into the 5½ short hours of the visit which lasted from 10.30 a.m. to 4 p.m. It is impossible to describe all that was seen; one can only pick on the highlights.

The transonic tunnel impresses with its size. Originally known as the high-speed tunnel, it has been renamed since it was modified by the installation of slotted walls in the working section. Suction is applied to these—pumps absorbing 8,000 h.p. are used—and in this way accurate tunnel results can be achieved through the transonic zone up to $M = 1{\cdot}2$.

A small scale model of the large transonic tunnel is being installed; it is operated by a by-pass drive from the suction pumps used for the main tunnel. Diffuser suction is used for the working-section walls of this tunnel, which is fitted with a Schlieren system for shockwave observation and can operate at speeds up to a Mach number of 1·4.

It was interesting to see the supersonic tunnels—the one we studied was of the intermittent type. It was being used for a basic investigation of the characteristics of different missile configurations. Strain-gauge balances are used and results automatically recorded on punched cards.

The hypersonic tunnel was seen under construction—the R.A.E. take hypersonic speeds as those from $M = 4{\cdot}5$ upwards. A feature of this tunnel is the elaborate system necessary to heat air to 600°C. before it enters the contraction of the tunnel. The expansion ratio is so great that the air would liquify in the working section if it were not preheated.

We saw a potent demonstration in the kinetic heating laboratory. Tubular infra-red heaters were arranged to project 35 kilowatts of heat over an area of one square foot. Under the heater was placed an aluminium alloy sheet. Power was switched on and within seconds the sheet wilted, drooped and melted. The heat input was that which an aircraft flying at $M = 4$ at sea-level would experience—having seen the demonstration, one can surmise that few aircraft are ever likely to be so rash as to do this.

Main work in this laboratory is devoted to the development of practical methods and techniques for kinetic heating. The electrical power which will be needed for full-scale structural tests under kinetic heating conditions will be immense, one gathers.

I have only described one or two of the most interesting things we saw at Farnborough—there were many more to be seen. And, undoubtedly, the most interesting of all lie behind the doors which secrecy bars to us.

For the fascination of this visit we must thank Mr. J. Sigrist, the R.A.E.'s energetic P.R.O., and all those who so lucidly explained their work to us.—J.R.C.

Visit to the Lotus Engineering Co.

A Visit is being arranged to the works of the Lotus Engineering Co. at Hornsey, London, N.8. Motoring enthusiasts will know that they are the constructors of the highly successful Lotus-Climax sports/racing cars and the brand-new Lotus-Climax Formula 2 racing car.

The works are small, so only a small party can be accommodated and those interested should write immediately to the Hon. Visits Secretary, N. K. Benson, 14 Wakering Road, Barking, Essex. The visit would take place on a weekday evening, but the actual date can only be fixed at short notice because it will depend upon the work the Company has on hand.

N. E. ROWE PRIZE PAPERS 15th JANUARY 1957—*See* Notices p. LX.

THE LIBRARY
Reviews

BALLOONS. *With an Introduction and Notes by C. H. Gibbs-Smith, Companion, R.Ae.S. Twelve coloured plates 16 in. by 11 in. The Ariel Press, London, 1956. 25s.*

As these balloons go up, the price goes down.

Here is a selection of coloured prints, from the period 1783-1820, which have been chosen for their pictorial quality, and not merely on account of their aeronautical or historical significance. With them goes the historical notes describing them, by C. H. Gibbs-Smith, and all for twenty-five shillings! The inflation of the balloons seems most clearly to deflate the costs. These coloured prints are generous in their size, enchanting to look at, and are just asking to be framed on the walls of the dwellings in which aeronautical enthusiasts choose to live when not up in the clouds of their own phantasies.

Gibbs-Smith betrays a polite urbanity towards balloons in general, and to these twelve in particular. "It would be hard to imagine a more decorative addition to the world's means of locomotion. With smoothly spherical, pear-shaped or other varieties of aerial embonpoint, *SHE*" (oh! large italics, please Mr. Printer!) "has now peopled the skies in many different textures and colour schemes, from the blue and gold Montgolfière that first 'enclosed a cloud in a bag.' . . ."

No woman likes to be praised for her embonpoint, or to be called a "bag." Fie, fie, Mr. Gibbs-Smith! You may claim that another used the phrase before you. But *this* is your own:

"The vertical and horizontal lines of buildings, trees and humans and especially tall thin and supporting masts —where they occur—combine with the plumpness of the envelope to produce a mood of calmness and repose; while the vehicle herself, by our mere knowledge of her behaviour, evokes a feeling of lightness and levitation, of ascension and escape."

I shudder when I quote further from his dulcet delivery.

"The hot air balloon—known as a Montgolfière—was suspended limp between two masts and inflated by having her neck held over a fire beneath the take off platform: another fire was lit in a brazier and then slung in the neck of the balloon to provide a continuous supply of hot air on the voyage."

Yet, perhaps I shudder too much, for there are, I freely admit, occasions in which I would have liked to have slung a brazier in the neck of those who talk hot air on the voyage.

But enough of this nonsense.

This is a book of colour and delight, which opens with that ever fascinating print in gay gold and deep sky blue, of the first aeronauts, Pilâtre de Rozier, as pilot, and the Marquis d'Alandes as the rich passenger, riding the sky on 21st November 1783, the first men ever to do so.

Eleven more coloured prints follow, and all have their stories told with airy abandon in the lively light of learning of Mr. Gibbs-Smith. It would be invidious of me to do more than indicate some of the prints, which have given such delight for well over 150 years and will continue, without doubt, to do so for another 150 or more. Here Blanchard, and the dollar-doctored John Jefferies are seen making the first crossing of the English Channel by air on a cold January day in 1785. The little French pilot lost his trousers on the voyage. There follows the first sailing balloon, with all sails set; and one which is powered by a pair of Eagles (shades of Rolls-Royce). The famous "La Minerve" is here, a floating phantasy, if ever there was one, with its attached cage for ladies of easy virtue; Madame Blanchard, the aerial show-woman who met her death in 1819 giving a firework display in a balloon; and the ascent of the first English aeronaut, James Sadler, at Oxford, among them.

"If there were dreams to sell,
What would you buy?"

These are dreams to sell, and I believe many will reply "Balloons" when they see this graceful publication.—J. LAURENCE PRITCHARD.

WAR IN THE AIR. *Gerald Bowman. Foreword by A.C.M. Sir Philip Joubert. Appendix of some aircraft of both World Wars. Index. 224 pp. Illustrated. Evans Bros. 16s.*

This book gains some publicity from having been based on 15 films previously televised under the same title. The TV version successfully appealed to large audiences through visual action. The book conveys no equivalent tense excitement.

The author's presentation of the development of war by airborne weapons is inhibited by his adoption of a formula for a different art. Air warfare in World War I is grossly underwritten, perhaps because few film shots were available for the original version. Among other omissions are: no reports of the bombing surveys in Europe and the Far East, no description of the longest-ranging, entirely strategic bombing of the U.S.A. 20th Air Force from the Marianas; going farther back, no mention of the fighter-bombers of the First World War.

The current excessive tendency to ascribe all victories in World War II to the value of air power is very obvious in this book. But deeper analysis must assess strength in all arms. In the German assaults of 1939-42, the Japanese onslaught in 1941-43, and the Allied come-back in 1943-45, the victors had *total* might on their side every time, except in the Battle of Britain.

Any attempt to tell such an immensely detailed story in so short a book must almost inevitably fall between two stools—to get narrative, detail must be omitted: to include detail drives the style down to the encyclopaedic. Bowman, weaving between these alternatives, garners the flaws of both.

Had the author been given twice the length, with freedom from the snare of a different media for his outline, he might have produced a work of some importance. But to do so he would have had to cut the propaganda, leave judgment to the reader.—NORMAN MACMILLAN.

SURVIVOR'S STORY. *By Air Marshal Sir Gerald Gibbs. Hutchinson, London 1956. 182 pp. Illustrated. 18s.*

Sir Gerald Gibbs has even got his modesty and discretion into the title of his book and those qualities run all through it. He allows himself no bursts of indignation against human folly or sardonic portraits of old-fashioned soldiers in modern wars, as did Sir John Slessor. He indulges in no revelations of inter-Service rivalries, as did Sir Philip Joubert. When he comes to what I have always taken to be a matter of tense disagreement on tactics in the Battle of Britain—the question of big or little formations of fighters, with Sir Trafford Leigh-Mallory and Sir Keith Park as antagonists—he explains

mildly that indeed they were agreed in principle and only disagreed about the wisdom of having something in reserve against the risk of being bounced. He ought to know, for he was at 11 Group while that commanders' battle was being fought, but he does not explain why Leigh-Mallory got the promotion and Park got shunted.

He does give the reader a good picture of the life an officer led between the wars on service in different parts of the world. It is a picture discreetly painted in the quiet colours a Victorian diplomat might have used and it is all framed, a little naively, in neat bits of advice for the traveller including such as take their golf clubs with them. Sir Gerald began his Service life in India and he finished it there when he handed over command of the Indian Air Force in 1947 to an Indian C.-in-C. He handed it over apparently with full confidence, having a high opinion of his successor and of the pilots. No one could suspect him of being a "blimp" and yet his book is written with all the reserve and restraint and sweet reasonableness that would have been right 50 years ago, before writers had become accustomed to the uninhibited processes of leaving nothing to be read between the lines.—E. COLSTON SHEPHERD.

FLY FOR YOUR LIFE. *Larry Forrester. Frederick Muller Ltd., London 1956. 367 pp. 18s. net.*

This is the Service biography of Wing Commander R. R. S. Tuck (who won the D.S.O. and the D.F.C. with Two Bars in the Second World War) and the story is excellently told. Tuck was an officer apprentice in the Merchant Navy before he joined the R.A.F. in 1935. Finding difficulty in going solo, he was almost turned down. That imprinted on his mind the wish to excel exceptionally in flying skill, and he continually strove to be better than any of his contemporaries as a pilot.

The author makes no attempt to gloss any of his faults —his rather arrogant and intolerant personality, the youthful binge and its aftermath which almost cost him his commission, his superciliousness as a "regular" towards R.A.F.V.R. wartime pilots. And he builds about him a series of coincidences, referred to as "Tuck's luck," which include his learning to speak Russian from a house-servant in early childhood standing him in good stead when he escaped from a German Stalag and crossed over the eastern front into Poland, his opportune skill in knife-throwing acquired from a Portuguese bos'un, his accurate shooting first encouraged by his father and improved against target sharks from the ship, and the way people who could help turned up at the right moment to assist Tuck when in trouble, together with the occasional providential escape from death by strange coincidence.

Tuck was fortunate to be chosen as a fighter pilot. Temperamentally he might have been wasted in either Bomber or Coastal Commands. He first went into action over the Dunkirk beaches. From the beginning he was the killer type of pilot. He believed that the days of the stalker, and of the lone duellist in the sky, who built up big scores in World War One, were over. Yet on one occasion he went far out alone over the North Sea, encountered several Me.109's, shot down two, barely escaped with his life, and had to bale out, being picked up by a small vessel. But his normal method was to fight in big formations, although at Dunkirk and in the Battle of Britain the British pilots were vastly outnumbered.

Tuck fought all through the defensive battle, with a gay recklessness that carried him through successive narrow shaves. He probably had as many aircraft written off under himself by shells, bullets, crashes, and stepping out, as the 29 enemy aircraft he was officially credited with destroying. His great quality was his deadly aim. Even in his last flight he shot up and killed the crew of an A.A. gun at the very moment he was approaching a dangerous crash landing in a glycol-leaking, badly-holed Spitfire.

His courage inspired others and enabled him to take command of and build up a demoralised Squadron. It rated him rival to Bader and Malan, and finally brought him down to be a prisoner of war, unco-operative, resolute, resistant, and an escaper who at length succeeded in reaching the Russian lines. He retired from the R.A.F. in 1949; we are not told why he did so, and is now farming in Kent. A text-book in "guts" rather than technique, a novelised biography of one of the best-known earlier Spitfire pilots that holds one's interest throughout, it has few points to criticise, and these are due to "popularisation" style rather than anything else.—NORMAN MACMILLAN.

WING LEADER. *"Johnnie" Johnson. Chatto and Windus, London 1956. 320 pp. Illustrated. 15s.*

J. E. Johnson was just becoming known in the R.A.F. as a promising fighter pilot when Stanford Tuck was brought down in France and captured in January 1942. He got into the R.A.F.V.R. as a pilot under training shortly before the war, and was mobilised in August 1939. When he first got on to operational Spitfires a badly-set, Rugby-broken collar-bone gave trouble under *g*, and his fingers began to go numb. He approached one of the M.O.'s privately. His Squadron and Station commanders thought he was suffering from cold feet, but when he instantly agreed to an operation to rectify the trouble, they changed their views.

Thereafter he flew from U.K. bases, and with 2nd T.A.F. from Normandy to Denmark, with only one spell off on staff duty at No. 11 Group H.Q. He finished the war as the supreme Allied fighter ace of World War II, with 38 accredited victories. His score appears strangely modest compared with the 100 claimed by Molders, 105 by Galland, and from 200 to 336 by other German *kanone*. Johnson writes that Joachim Marseilles on one day claimed 17 victories in the Western Desert, but if he had in fact shot down all the types he claimed his score could not have exceeded nine, and some of those nine were downed when Marseilles was on the ground. One wonders where the German pilots learned addition?

Written by Johnson himself, this book does not have the narrative polish of a professional author. Yet it is intensely interesting, because it relates the story of the second half of the war, after all the early stars had set from death, capture or promotion. He saw little or nothing of the defensive fighting in which Tuck, Bader, Malan and others gained their glory. And so, with their lessons learned, and with skies freer from German domination, there was more opportunity to study and develop fighter strategy and tactics, and for that reason he writes more on this theme, and disagrees with earlier theorists like Bader.

We see the tight V-formations of peacetime exercises and displays broken up by the hammer of battle. Johnson gives credit to the Luftwaffe as first to find the best fighter formula for combat, the elements of two-fighters flying in "finger-four" formation. The Luftwaffe learned its job in Spain. But Johnson may not know that the R.F.C. used the two-fighter element in 1917. Johnson supports Keith Park's strategy against that of Leigh-Mallory in the Battle of Britain. He holds that the Wing of two squadrons was the largest practical fighter formation.

After D-day it became a squadron and flight commanders' war, and in Korea a flight commander's only, for tactics in the air. In France it was found that if a Group Captain co-ordinated three Spitfire Wings (9 squadrons) it was too cumbersome for tactical operations in the field. Thereafter a Group Captain commanded a Wing of only three or four squadrons, with a Wing Commander as leader.

Johnson has many good descriptions of air fights, but they are sandwiched among strategical and tactical views, personality snapshots, and shifts of timing in the tales. More than any other author with World War II operational experience he gives the reader the real individual gen on the development of air fighting in that war. No doubt it was because he fought with his head that he gained his victories and his triple D.S.O. and double D.F.C., five foreign decorations, and is now a serving Group Captain in the present R.A.F.—NORMAN MACMILLAN.

LONELY WARRIOR. *The Journal of Battle of Britain Fighter Pilot, Jean Offenberg. Edited by Victor Houart. Souvenir Press, London 1956. 239 pp. Illustrated. 18s.*

The best of the exiles who fought with the R.A.F. brought an intensity to their task which turned it virtually into a private crusade. Jean Offenberg, of the Belgian Air Force, was one such. He is not properly to be described as a Battle of Britain pilot, for he did not get into the fighting until October 1940; and by then the Luftwaffe had lost that battle, but in the ensuing eighteen months he had combats by the score. He was continually in dispute with his superiors about the amount of flying he could be allowed to do. He invariably came back from leave a couple of days too soon. He was "carpeted" for turning a test flight into a single-handed (and successful) offensive patrol. When he found himself away from the thick of the fighting, black despair settled on him and he pulled all the strings he could find to get himself transferred back into 11 Group. He rarely got hit, for he had unusually good sight. He was unconcerned about the tally of his kills, for a cool caution forbade him to follow his victims down and his passion to go on killing kept that caution ice-cold even when he was sweating copiously in the fierce chaos of a dogfight. In the end he was killed by a youngster who used him, without his knowledge, as a target in a mock combat and collided with him.

Offenberg was not in fact a lonely man. He usually had from six to twelve of his fellow-countrymen with him in the same squadron. He joined in the squadron parties, yet he never started them. He grieved, perhaps more than most, over the loss of close friends. He was a devout man, so devout that he grumbled when operations kept him away from a Sunday mass, but while his fighting life lasted, he was dedicated to shortening the war and grumbled much more when there were no combats to be had. This picture of the man comes out of his diaries. His entries do not ring with a passionate patriotism like those of Mouchotte, the Frenchman, but there is the same longing to see home again, the same burning desire to hasten the day, the same devotion to the techniques of air warfare so that no chance be lost. In that sense, all these exiles fighting for their past, were lonely men. Their purpose was the only thing for which they could find room. As his editor says: "The foreigners here were not mercenaries; they did not fly and fight for the British, they flew with them." Their sort of devotion may never appear again in a similar setting. At the cost of some repetition, as books about the air war pour from the presses, it is good that stories like Jean Offenberg's should be told. A little more care in preparing it for publication would have prevented silly mistakes like turning 11 Group into 2 Group and crediting the Spitfire with an armament of 220 mm. cannon.—E. COLSTON SHEPHERD.

SWASTIKA IN THE AIR. *The struggle and defeat of the German Air Force. By Karl Bartz. Translated by Edward Fitzgerald. William Kimber, London 1956. 18s.*

Like all apologia, this book has to name culprits. The ones chosen are Hitler, the blind dictator, and Goering, the boastful, idle, voluptuous toady. Both have been indicted before, notably by Gen. Galland. The charges made by Herr Bartz are not much different. Hitler prevented the Luftwaffe from having an adequate fighter force because of his obsession with the offensive. He stopped a great deal of experimental work in 1940 by a general order forbidding any such work unless it would yield practical results within a year. (Radar suffered heavily; jets escaped the ban through a subterfuge on the part of Udet.) When jet fighters arrived, Hitler had them turned into bombers and then, under pressure at the end of 1944, back to fighters. An excellent four-engine bomber, the Ju.288, was never put into production.

In all these matters, Goering made no serious attempt to influence Hitler. He was even guilty of his own stupidities such as the suppression, in 1941, of all work on countering the effect of "window" on radar. The value of Herr Bartz's book is not in its revelations or in its explanations of why the Luftwaffe was overborne but in the neat fitting of the air war, as seen from the German side, into the general picture of the campaigns on all fronts. Under this system, for instance, he shows why air supply could not save the army of Gen. Paulus at Stalingrad and how its refusal to retire in time and Hitler's refusal to order retirement made the futile and costly air lift unavoidable. As an account of air operations set in the frame of bigger operations, this book is worth reading. The "alibis" are insidious. The reader is apt to believe them and, by the same token as Stalin's successors now excuse themselves, let out those who make their belated protests with the remark: "They would have been shot if they had protested then." I wonder.—E. COLSTON SHEPHERD.

THE QUICK AND THE DEAD. *The story of a chief test pilot. By Squadron Leader W. A. Waterton, G.M., A.F.C. and bar. Muller, London 1956. 237 pp. Illustrated. 15s.*

Few of us have ever had a boss we agreed with all the time. Some of us have never had a boss we fully approved. Even in the R.A.F., "Bill" Waterton says he was described on his confidential report as a most reliable and excellent officer but "a rebellious character." That must provide the key to a book which is spoiled by recurrent indictments of the company that employed him and of the British aircraft industry in general on charges of failing to act on test pilots' advice, of making do for the sake of sales and of risking pilots' necks by pressing on with tests without first correcting faults.

He goes so far as to say that the "boffins" never forgave him for bringing back the evidence on the occasion when the first Javelin's elevators were broken by flutter and he nearly lost his life. That is a measure of the anger and resentment, for the expression of which this book is made a medium. In so fine a pilot, the parading of grievances is to be regretted unless they could be marshalled objectively and made the basis of coolly constructive proposals. In this instance they mar an intelligent and often exciting story of test and

demonstration flying, and give a false impression of one whom many of us know as an admirable companion.—E. COLSTON SHEPHERD.

THE BRABAZON STORY. *Lord Brabazon of Tara. Heinemann, London, 1956. 227 pp. Illustrated. Index. 25s.*

Purely from the aviation point of view this is in some ways a disappointing book. There is much of interest in it, but it is not the Brabazon story those in aeronautics would expect; it is Lord Brabazon "reminiscing" on his many interests, talking a little of his early life, his early motor racing days, of golf, sailing, politics, the Cresta run—talking delightfully and entertainingly as one would expect, with his great sense of enjoyment in all he did shining through and much of his philosophy of life. Perhaps it is the shock of finding that the air merits only two chapters out of 14, which leaves this reviewer, at least, disappointed. Those two chapters are "In the Air"—15 pp.—about ballooning, and "In the Air Again"—21 pp. (with, alas, one or two errors) which ends with the death of the Hon. C. S. Rolls in 1909—when Lord Brabazon's practical flying ceased. Later there is a little on his time as Minister of Aircraft Production but not a mention anywhere of the Brabazon Committee.

In all fairness Lord Brabazon himself calls his book "random reminiscences" and warns the reader in his foreword that "anyone with only one subject is a bore," but he also says "sometimes I think history devotes too much to events and neglects the atmosphere of the surroundings." There is so much in British aviation in which he has been so closely concerned, and which only he with his pithy comments could tell us. Someday someone may write the story of Lord Brabazon and aeronautics but they will not recapture for posterity the atmosphere which only "Brab," of "Fly one" fame, could do in his delightful way.—J.B.

THE REPORT ON UNIDENTIFIED FLYING OBJECTS. *E. J. Ruppelt. Gollancz, London, 1956. 315 pp. 18s. 6d.*

FLYING SAUCERS COME FROM ANOTHER WORLD. *J. Guieu. Hutchinson, London, 1956. 248 pp. 12s. 6d.*

The curious thing about the Flying Saucer controversy is that the detractors can be almost as unscientific and hysterical as the proponents, and as much powered by wishful thinking. Thus one learned professor explains all the phenomena as resulting from temperature inversion—apart of course from mis-sightings and faking with dustbin lids—an explanation as ludicrous as that which sees them all as interplanetary vehicles manned by little rubbery men with antennae sticking out of their ears.

These two books represent the sober reporting of a man (Mr. Ruppelt) who was in charge of one of the official investigations, and the indiscriminate garnering (by Monsieur Guieu) of facts, fables and nonsense with no effort to sort one from the other. "Jimmy" Guieu offers us a well-told farrago of tales—without appraisal—and some bewildering photographs, one of which shows a saucer over Paris with the Eiffel Tower touched in by hand so clumsily that it would not convince a child. There is little to say about such a book except to recommend it as in-the-bath reading for those who are primarily interested in aeronautical folklore. There are many of the classic and important unsolved cases included too, but they are so tainted by being neighbours to credulity that even they themselves almost lose caste.

Mr. Ruppelt, on the other hand, never advances an explanation of what is inexplicable, and reveals the most interesting explanations of many stories which the United States Government were handed by both the public and by highly respectable observers. If the reader of this review is not an hysterical anti-saucerer, and if he is really interested in facts as possibilities, he should read this book: for some of the "sightings" have defied every scientist and every reasonable explanation that can be offered.

I would also pray such a reader to bear in mind (*a*) that such eminent engineers as Hermann Oberth had said that some saucers may be interplanetary in origin; (*b*) that the science of electro-gravities is in its infancy—an infancy almost as shrouded by security as was the atom bomb—which may revolutionise our whole conception of propulsion and space-flight; (*c*) that space travel is almost on our own doorstep after only fifty-odd years of powered flying; (*d*) that all reputable astronomers estimate the number of probably inhabited worlds in the universe as thousands, if not millions; (*e*) that many of those worlds have probably tens of thousands of years of civilisation behind them; and (*f*) that our own world is a somewhat second-rate affair with a conceited but nonetheless infant history of some three or four thousand years alleged civilisation.—C. H. GIBBS-SMITH.

NO MOON TONIGHT. *D. E. Charlwood. Angus and Watson. 1956. 221 pp. 12s. 6d.*

Charlwood was one of 20 men who sailed together from Australia to join the R.A.F. He was a Navigator who survived his tour of 30 raids—all with the same crew. Only four others of the 20 are alive at the end of the book, which is factual.

That is the barest outline of a book which, were I to give my enthusiasm full rein, I could go on reviewing for pages. The soft pedal is kept right down the whole time but rarely have I seen conveyed so well the misery of departed friends, the comradeship of shared and survived hazards, the beauty of a wartime love affair (why was it so hopeless?), the swineishness of one in authority. There is no unnecessary bad language for the sake of bad language, no sex for the sake of sex, no false heroics or emphasis on the dangers and rigours of each raid. Every now and again, when he is on leave, a choice little passage breathes the poetry of the English countryside with the skill of a Blunden or a Belloc.

Were I allowed one war book on my desert island, this would be it.—F.H.S.

THE PROVING FLIGHT. *David Beaty. Secker and Warburg, London, 1956. 282 pp. 14s.*

The proving flight of the new turbo-prop airliner Emperor was more eventful than we hope is usually the case. The machine is claimed to be the final answer to trans-Atlantic travel, capable of operating non-stop from London to New York even against the strongest headwinds. With a load of V.I.P.'s, which include the Chairman of Air Enterprises Ltd. and the Under-Secretary for Air, the aeroplane battles on against the weather, a mechanical failure and the conflicting temperaments of its passengers and crew. The book is well written, drawing from the author's first-hand operational experience, for he is an ex-B.O.A.C. trans-Atlantic pilot; it is exciting and very readable. (This, of course, is fiction!)

THE DARK HAVEN. *F. T. K. Bullmore. Jonathan Cape. London, 1956. 192 pp. 15s.*

An unconventional and entertainingly written book on a little-known branch of the Royal Air Force by a pilot of wide service and civil flying experience. A warrior who fought zealously to save lives, Wing Commander

Bullmore tells of the initiation and development during the 1939-1945 War of F.C.L.O.—Flying Control Liaison Officers—the organisation within Flying Control which was responsible for guiding home and landing safely—or rescuing—so many "lost" and crippled aeroplanes.

MEN, ROCKETS AND SPACE. *Lloyd Mallan. Cassell, London, 1956. 303 pp. Illustrated. 18s.*

In his Foreword to this well-produced book of American origin, Lt.-Gen. T. S. Power (Commander of the U.S.A.F. Research and Development Command) writes that the author "has filled a long-felt need by presenting the story of some of the contemporary aeronautical pioneers. While writing about little-known aspects of their personal lives, he portrays their technical and scientific achievements in a manner designed to be both understandable and interesting to the layman." This is a very fair description of the work; it is not, as its title might suggest, yet another popular book on interplanetary travel. In it, one finds a very full treatment of all the vast amount of work now going on in the States on what might be described as the frontiers of aviation: the flights of pilots such as "Chuck" Yeager, Bill Bridgeman, Pete Everest and Scott Crossfield in the X-1, X-2 and "Skyrocket"; the aero-medical experiments on high-altitude flight, weightlessness and exposure to cosmic rays; the various tests carried out with such rockets as the V.2, Viking and Aerobee; the founding of the Reaction Motors and Aerojet rocket engine companies, and many of the great American research facilities, like Muroc and White Sands—even a chapter about radio astronomy.

Lloyd Mallan seems to have been given special privileges and facilities to travel around and interview all the key people engaged in these important endeavours, and to have made a sincere attempt to capture their true atmosphere and significance. There will be a great deal in his book to interest and inform anyone connected with aeronautics—by no means only the laymen. However, he embarked on such a worthy effort that it is a great pity he did not better succeed. At least for this British reader, there are three reasons for his failure.

First, the book is much too long—in trying to be exhaustive, with something approaching 180,000 words, the author has more nearly succeeded in being exhausting; a not uncommon trans-Atlantic literary failing. Secondly, he has an oddly uneven style, lapsing sometimes (one gets the impression, against his own will) from the soberly factual into the Sunday newspaper. (One wonders how Major Murray liked this description of himself: "An exceedingly handsome male, tall and slim, blue-eyed and blond, with crisp enunciation, an unfaltering flow of speech and genteel manners, . . . more like a high-born scion of leisure than a test pilot who tames wild rocket aircraft.") Thirdly, the explanations given for technical phenomena can often best be described as half-baked; for example—"Aerodynamic heating, as it is sometimes called, can be described more simply as the heat generated when two solid objects are rubbed violently against each other—one of these objects is the metallic aircraft and the other is the solid surfaces of compressed air surrounding it and resisting its passage."

Occasionally, these last two faults are combined, with results truly awful in both the modern and the literal senses. I am sure my good friend Sid Allen of Armstrong-Siddeley's will be horrified to learn of liquid oxygen that "its synonyms are ominous in any language . . . DANGER the English . . . a turmoil that can explode spontaneously into a shower of destruction." The author is quite impartial, however; later on, one meets this nonsense about concentrated hydrogen peroxide—"a drop of this undiluted chemical could burn a ragged hole through human flesh with the suddenness of a lightning bolt."

On the other hand, all rocket engineers could enjoy the description of their kind of power plant as "a controlled catastrophe."

Probably the best parts of the book are those on aviation (and space) medicine. From these, without in any way intending to minimise the importance of their subject, one cannot resist selecting for comment two pages which deal with the physiological phenomenon known in other circles as "Chapel bottom." They are entirely worthy of Beachcomber's immortal Dr. Strabismus.

It appears that the Aero-Medical Laboratory at Dayton set out to investigate the problems of sitting-fatigue, with the loyal co-operation of a number of dedicated young aircrew members, who must have realised that, even if they could no longer fly by the seat of their pants, at least they had to sit on them. One of the first discoveries of this team of investigators was hardly surprising: fat men make more suitable chairborne types than thin ones. However, the study proceeded; instrumentation was developed "to measure the positions and pressures of the ischial tuberosities in a seated man." They "added a large diagonal mirror to cast the buttock image on a vertical screen . . . the critical bone-pressure areas were revealed as bright spots." Finally, a very sophisticated foam-rubber air cushion was evolved. It incorporated self-adjustment to a suitable pressure for the individual sitting on it, an automatic barometric control to compensate for varying ambient conditions, and—best of all—"a pulsating effect to massage the buttocks," no less. With the aid of this superb device "four volunteers of different physical characteristics each sat in a grounded F-84 for fifty-six hours" and "no subject had to be lifted out of the cockpit and carried away to a hospital bed with blood blisters on his buttocks." It is not recorded whether earlier, less fortunate, human guinea-pigs were decorated with the Purple Heart. Or if so, where.

There is at least one section of the book which is of lasting value and very great interest, likely to be quoted increasingly in the years to come. This is the concluding Chapter XIV, representing the recorded results of interviews by the author with some two dozen different qualified pilots, engineers, doctors and scientists in various fields, on the question of their attitudes towards the prospects for space flight. It is significant that none of them ruled it out as impossible, and in fact nearly all expected it to be achieved at some time in the future, near or far. Within this broad generalisation, however, their reactions varied from an intense enthusiasm, through a more qualified one (which in some cases bordered on an acceptance of what was believed to be inevitable), right down to the argument that the probable results from the immense effort involved did not make it worthwhile. The majority view tended towards the enthusiastic end of the scale, and the argument that, if the Americans did not do it, the Russians would, also appeared.

Perhaps the most representative comment came from Jay Demming, an engineering test pilot with North American. He said, . . . "the coming of space flight is just something as obvious as the nose on your face. You can use your own imagination when I say that some of the things we are now doing towards development of future aircraft actually borders on fantasy. Every day the altitudes get higher and the speeds get faster—and one of these days you'll automatically call it space travel."

As Mr. Mallan himself concludes, these words summed up neatly the theme of his book. Even if it is not quite

what one might have hoped, it has much to commend it, and at least its author had the right basic idea.—A. V. CLEAVER.

TECHNICAL ASPECTS OF AIR TRANSPORT MANAGEMENT. *R. Dixon Speas. McGraw-Hill, New York, 1955. Illustrated. 64s.*

A new book on air transportation from McGraw-Hill is certain to arouse the keenest anticipation and in this case especially so for the earlier volumes by Mr. Dixon Speas were much read in this country. Certainly in its production format and illustration this book reaches the high standard which we have come to expect from the best American technical publications since the war. Over £3, however, is a high price for a book of this kind and will prevent it from achieving the widest reading and attention. The author has covered an extensive field. His sixteen chapters range from an historical summary and airline organisation, to the fundamentals of flight performance, cruise control methods, meteorology and communications. He compresses a surprising quantity of matter into his 300 odd pages and his selective judgment is nicely balanced, although the style was marred for this reviewer by an impression gained of over-hasty preparation.

A strong emphasis on reciprocating engines and their cruising control in comparison with the current problems with turbine engines was noted. This will cause disappointment to many readers and must surely date the work prematurely. A final chapter on Turbine Powered Transports seems barely adequate for so important a subject.

It is clearly not possible for the Air Transport engineer or consultant to keep intimately in touch with progress in all the diverse fields of activity now engaging specialised effort in the fast growing industries of civil aviation. It is probably for this reason that we value so much today technical journals and periodicals giving a special emphasis to progress in our particular field of work. It might even be thought that the editing of specialised contributions was more fruitful than the writing of a general book such as the one now under review. But the executive and the non-specialist is very much in need of a broad appreciation of the subject and Mr. Dixon Speas has wisely stimulated the interest of his reader with a nice selection of the most crucial topics for discussion. He has shown that the technical aspects of air transport can be set forth in a digestible form which many readers would find it difficult to assimilate otherwise without extensive reading and discussion.

For newcomers to the industry and students, however, this volume only partially fulfils the need. References are of the utmost importance in a book of such scope. Unfortunately in few cases are the data in this volume coupled with a source, and references are such a notable omission that the book could not be recommended to students unless further guidance was at hand.

The European reader may become restive with the essentially American approach to the subject and the primary emphasis on U.S. domestic operations. In a work that could have such point and significance to the English reading members of the air transportation and manufacturing industries an international view would have been preferred. A specification of 24 transport aircraft gives only U.S. designs and the facts and figures of air transportation outside the United States are not considered. However, the United States provides the most highly developed and best documented airline system in the world today and the examples cited and the conclusions reached in this work are unimpeachable even if not all inclusive.

This book then will provide stimulating reading to the non-specialist with a need to broaden his knowledge of the progress in the techniques of air transportation, principally in the U.S. since the war.—A. H. STRATFORD.

MOLYBDENUM. *L. Northcott. Butterworths, London, 1956. 222 pp. Illustrated. 40s.*

If a history of metallurgy were written, it might well start by stating that in the beginning there were some 76 metals. It would continue, somewhat in a minor key, by admitting that until the beginning of the Bronze Age, perhaps more than 7,000 million years later, they were, from the human point of view, as if they were not, for they were unknown. In the last 6,000 years, however, Man, initially very slowly, but now at a rapidly increasing pace, has got to appreciate some of these metals, but for at least half of them, he still has to find a use.

Molybdenum, to which Dr. Northcott's monograph is devoted, is by no means a new discovery. From classical times until three-quarters of the way through the 18th century, its disulphide, for very understandable reasons, was confused with galena, graphite and plumbago. Then in Sweden there came a curious chain of discovery. First Bergman discovered and to some extent inspired Scheele, who, *inter alia*, discovered molybdic acid, to be followed some twelve years later by Hjelm's discovery of the metal itself. It was not, however, until over a century later that any real metallurgical use was made of it. Not until after the First World War was it realised that molybdenum possessed remarkable power in combating temper brittleness in nickel chromium ferritic steels addicted to the disease known as Kruppskrankheit. Further, more time was to elapse before it was established that as a constituent of certain austenitic steels it could improve their corrosion resistance, particularly when exposed to sulphurous acid and, at elevated temperatures, markedly increase their rupture strength. Such, as far as aircraft structural and power plant materials of today are concerned, is the position with regard to molybdenum. It is a minor, but very important constituent of certain steels. S.96 and S.99 contain about 0·5 per cent, so in a "V" bomber airframe there are between 30 and 40 pounds of the metal. Tomorrow, however, because of its high hot strength, it may, in spite of a marked susceptibility to oxidation, become the basis of useful heat resisting alloys.

So much for molybdenum, now for Dr. Northcott's monograph on it. Books come into being in divers ways. Homer declaimed and his words echoing down the ages, were remembered, to be written down years later. Blind Milton dictated to his daughters. More ordinary mortals, like the writer, use paper, pen and ink. Dr. Northcott, however, has greatly relied on a pair of good scissors. He has cut from many publications, largely of American origin. He has arranged his abstracts in logical sequence, but he has sometimes neglected to present the temperatures and stresses recorded in some of them in the manner usual in this country. Further, he is very sparing in his commentaries and finally, like many learned men, he has produced a very poor subject index. Forty shillings is a lot to pay for this work of two hundred and twenty-two pages. Picked up in a Library, however, it might well be found to contain useful information or perhaps better, to provide a guide to where such information could be obtained.—P. L. TEED.

ROLL BACK THE SKY. *Ward Taylor, Wingate, London, 1956. 363 pp. 15s.*

A novel of U.S. Air Force bomber operations against Japan from Saipan and specifically the story of one pilot,

his thoughts, emotions, his crew and his love for his wife in the U.S.A. and a nurse on Saipan. Rather too much psychological introspection but the author served as a bomber pilot in the U.S.A.F. and the combat side of the story is interesting.

JULES VERNE, MASTER OF SCIENCE FICTION. *I. O. Evans. Sidgwick and Jackson, London, 1956. 236 pp. 12s. 6d.*

This is a selection from the writings of Jules Verne, with an Introduction containing a review of his life and his work.

There is an excellent bibliography at the end, of which the titles are enough to whet the appetite and, if his books are no longer shelved in the local Public Library, the Society can offer "From the earth to the moon direct in 97 hours 20 minutes and a trip round it" and "The clipper of the clouds" or, if you prefer French, "Cinq semaines en ballon." The Society can even produce "Las escursiones aerostaticas" which seems to be unknown to Mr. Evans.—F.H.S.

LORRAINE SQUADRON. *Paul Lambermont. Translated by Anthony Pirie. Cassell, London, 1956. 196 pp. Illustrated. 13s 6d.*

First known as the "Free French Flight" when it was formed in Equatorial Africa in 1940, the Lorraine Squadron of the Royal Air Force served in the Middle East, then from England and finally from bases in France. Written by an ex-member of the Squadron, simply and with restraint, and with extracts from official documents, this book is the story of the Squadron, and some of its operational flights, from its inception in Africa in 1940 until its final sortie from France in May 1945. Appendices include descriptions of the aircraft flown by the Squadron (Blenheims, Bostons and Mitchells), official mentions in despatches and equivalent R.A.F. and French ranks.

AIRPORT VISITOR AND AIR TRAVELLER 1956. *Edited by C. W. Cain. Penman Enterprises 1956. 72 pp. Illustrated. 2s. 6d.*

The increase in price by 6d. of this annual cannot be grumbled at. The format remains much the same, the contents have been brought up to date and the cover design has been streamlined. It is good value still.

THE ZEPPELIN STORY. *Thor Nielsen. Translated from the German by Peter Chambers. Allan Wingate, London, 1955. 239 pp. 17s. 6d. Illustrated.*

This is the story of the German airships and of Dr. Hugo Eckener who made them so famous throughout the world before the War. Strange are the ways of fate that this man who was first an economist and then interested in experimental philosophy, should, almost against his will, have found himself first reporting on the Zeppelins for a German newspaper and then devoting the rest of his life to them. Stranger still to ponder the course history might have taken had he become President of the Reich before Hitler gained power. An interesting book. One minor point, it was the British Gold Medal which the Society awarded Dr. Eckener in 1938, not the Society's Gold Medal.

BEST FLYING STORIES. *Edited by J. W. R. Taylor. Faber and Faber, London, 1956. 315 pp. 15s.*

One ceases to marvel at Mr. Taylor's output and merely wonders at the methods he employs to transfer writing on aeronautics on to a conveyor belt. One must now admire his bravery in putting his editorship to "Best Flying Stories." You take the selection or leave it (most of the best names are there) but anyway its a good book to take on a train or have at your bedside.—F.H.S.

MILITARY AIRCRAFT OF THE WORLD. *By the Associate Editor of "Flight," Iliffe, London. 1956. 68 pp. Illustrated. 3s. 6d.*

This is a reprint from *Flight* of 8th June 1956, comprising a 60-page review of current military aircraft, with the history of their development and up-to-date technical details. An 8-page art supplement has been added to the reprint and this contains some unusual and attractive action photographs.

Additions to the Library

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* *Items marked thus are for reference use only*

Reports

AERODYNAMICS

Boundary Layer

See also Compressible Flow

Pressure and boundary-layer measurements on a two-dimensional wing at low speed. G. G. Brebner and J. A. Bagley. R. & M. 2886. (1956).

Results are given of pressure measurements and boundary layer traverses on a two-dimensional wing with 10 per cent R.A.E. 101 section at Reynolds number of $1{\cdot}6 \times 10^6$ and $3{\cdot}2 \times 10^6$. These results, which have been integrated to give lift, drag and aerodynamic-centre characteristics, are used to check some calculation methods for the growth of the turbulent boundary layer and for the effect of a known boundary layer on the pressure distribution.—(1.1×1.10.2.1).

Théorie et expérimentation des éjecteurs supersoniques air-air. J. Fabri et J. Paulon. O.N.E.R.A. Note Technique 36. (1956).

L'extrapolation des performances des éjecteurs classiques à flux moteur supersonique à des installations d'essais de grande puissance nécessitait l'établissement d'une théorie aérodynamique prenant en compte l'influence des divers paramètres géométriques, aérodynamiques et mécaniques définissant les conditions expérimentales. La vérification des prévisions théoriques sur un montage de laboratoire montre la réelle concordance des résultats du calcul et de l'expérience dans de larges conditions de frottement.—(1.1.3.1).

Compressible Flow

The subsonic flow past swept wings at zero lift without and with body. D. Küchemann and J. Weber. R. & M. 2908. (1956).

The effects associated with the subsonic inviscid flow past swept wings at zero lift are reviewed. Detailed solutions for incompressible flow are given for three basic cases:—(*a*) the sheared wing of infinite span; (*b*) the centre section of a swept wing of infinite span; (*c*) the flow in the curved intersection line between wing and body. These solutions are used to find approximate solutions for any given wing of infinite aspect ratio. The Prandtl-Glauert procedure is extended and applied to derive approximations for the compressible flow in the subcritical region. The special cases treated in detail are: the flow in the tip regions of wings; tapered wings; wing-fuselage interference for symmetrical arrangements; and modifications to the wing or to the body shape, for instance to restore sheared-wing conditions.—(1.2.1.1 × 1.10.1.2).

Diagrammes pour le calcul des éjecteurs à flux moteur supersonique. E. Le Grivès et al. O.N.E.R.A. Note Technique 35. (1956).

On présente un ensemble de diagrammes permettant la détermination rapide des caractéristiques d'extraction d'éjecteurs air-air à flux moteur supersonique. Le choix des paramètres géométriques et aérodynamiques a été fait de façon à satisfaire les exigences pratiques les plus variées, aussi bien du point de vue de l'air moteur disponible que de celui des performances souhaitées. Un diagramme supplémentaire rassemble enfin les conditions de configuration géométrique et de source motrice optimales pour chaque point d'adaptation donné.—(1.2.3.1).

Zusammenfassende Darstellung und Erweiterung des Aequivalenzsatzes für schallnahe Strömung. F. Keune. D.V.L. Bericht Nr. 8. (*July* 1956).—(1.2.2.1).

Der gewölbte und verwundene Tragflügel ohne Dicke in Schallnähe. F. Keune. D.V.L. Bericht Nr. 13. (*April* 1956).—(1.2.2.1).

Calculations of the flow over an inclined flat plate at free-stream Mach number 1. *W. G. Vincenti et al. N.A.C.A. T.N.* 3723. (*August* 1956).

A numerical solution is given of the complete equations of inviscid compressible flow for the case of an inclined flat plate at free-stream Mach number of one. The calculations are carried as far as the end of the separated region that appears on the upper surface of the plate near the leading edge. The results, which are for an angle of attack of 13°, show the pressure distribution on the lower surface and the detailed flow field about the lower surface and the leading edge.—(1.2.2.1 × 1.10.1.1).

Characteristics of four nose inlets as measured at Mach numbers between 1·4 *and* 2·0. *G. B. Brajnikoff and A. W. Rogers. N.A.C.A. T.N.* 3724. (*August* 1956).

The performance characteristics of two open-nose and two conical-shock diffusers were measured at supersonic speeds between $M_0 = 1{\cdot}4$ and 2·0 at angles of attack of 0°, 3°, 6°, and 9°. Schlieren photographs of flow about the models at 0° angle of attack were used to calculate external wave drag.—(1.2.3).

Theoretical and experimental investigation of the subsonic-flow fields beneath swept and unswept wings with tables of vortex-induced velocities. W. J. Alford. N.A.C.A. T.N. 3738. (*August* 1956).

The flow characteristics around swept and unswept wings necessary in first-order estimations of aerodynamic loadings, trajectories, and jettison characteristics of missiles, fuel tanks, or bombs as determined experimentally are compared with the flow fields as calculated by potential-flow theory.—(1.2.1.1 × 1.10.1.2 × 1.6.1).

Attenuation in a shock tube due to unsteady-boundary-layer action. H. Mirels. N.A.C.A. T.N. 3278. (*August* 1956).

A method is presented for obtaining the attenuation of a shock wave in a shock tube due to the unsteady boundary layer along the shock-tube walls. It is assumed that the boundary layer is thin relative to the tube diameter and induces one-dimensional longitudinal pressure waves whose strength is proportional to the vertical velocity at the edge of the boundary layer. The method is shown to be in reasonably good agreement with existing experimental data.—(1.2.3.1 × 1.1).

Internal Flow

A detailed experimental comparison of axial compressor blades designed for free vortex flow and equivalent untwisted and twisted constant section blades. S. J. Andrews and H. Ogden. R. & M. 2928. (1956).

Six stages of both twisted and untwisted constant section or "strip" blades were tested at a low speed in the 106 compressor. The performance is compared with that of six stages of equivalent free vortex blades, and inter-stage flow traverses provide the more detailed flow information.—(1.5.2.1).

Analysis of laminar incompressible flow in semiporous channels. P. L. Donoughe. N.A.C.A. T.N. 3759. (*August* 1956).

Perturbation solutions for laminar incompressible flow in semi-porous and fully porous channels are compared. The perturbation parameter measures the amount of suction or blowing at the porous wall.—(1.5.1.1).

Loads

See also Compressible Flow

Method for calculating the aerodynamic loading on an oscillating finite wing in subsonic and sonic flow. H. L. Runyan and D. S. Woolston. N.A.C.A. T.N. 3694. (*August* 1956).

A method is presented for calculating the loading on a finite wing oscillating in subsonic or sonic flow. The method is applicable to any plan form and may be used for determining the loading on deformed wings. The procedure is approximate and requires a numerical integration over the wing surface.—(1.6.3).

The interference effects of a body on the spanwise load distributions of two 45° *sweptback wings of aspect ratio* 8·02 *from low-speed tests. A. P. Martina. N.A.C.A. T.N.* 3730. (*August* 1956).

Tests of two wing-body combinations have been conducted

NOTE.—*The figures in parenthesis at the end of each Summary are for office use only.*

in the Langley 19 ft. pressure tunnel at a Reynolds number of 4×10^6 to determine the effects of the bodies on the wing span load distributions. The wings had aspect ratios of 8·02, taper ratios of 0·45, and incorporated 12 per cent thick aerofoil sections streamwise. One wing was untwisted and uncambered; the second wing was twisted and cambered. Identical bodies of revolution of 10:1 fineness ratio were mounted in mid-high-wing positions. The effects of wing incidence, wing fences, and flaps were determined for the plane wing.—(1.6.1. × 1.10.2.2).

Probability and frequency characteristics of some flight buffet loads. W. B. Huston and T. H. Skopinski. N.A.C.A. T.N. 3733. (*August* 1956).

The frequency characteristics and statistical properties of the buffet loads measured on the unswept wing and tail of a fighter aeroplane have been studied in the stall and in the shock régime. The results indicate that the wing loads in buffeting can be treated as the Gaussian response of a simple elastic system. The tail loads appear to represent a more complicated process.—(1.6.3).

Thermo-Aerodynamics

Investigation of the laminar aerodynamic heat-transfer characteristics of a hemisphere-cylinder in the Langley 11-inch hypersonic tunnel at a Mach number of 6·8. D. H. Crawford and W. D. McCauley. N.A.C.A. T.N. 3706. (*July* 1956).

A programme to investigate the aerodynamic heat transfer of a non-isothermal hemisphere-cylinder has been conducted in the Langley 11-inch hypersonic tunnel at a Mach number of 6·8 and a Reynolds number from approximately $1{\cdot}09 \times 10^5$ to $1{\cdot}03 \times 10^6$ based on diameter and free-stream conditions.—(1.9.1).

Aerodynamic mixing downstream from line source of heat in high-intensity sound field. W. R. Mickelsen and L. V. Baldwin. N.A.C.A. T.N. 3760. (*August* 1956).

Theory and measurement showed that the heat wave downstream from a line source is displaced by a transverse standing sound wave in a manner similar to a flag waving in a harmonic mode.—(1.9.2).

Wings and Aerofoils

See also Boundary Layer, Compressible Flow

A simplified treatment of a fixed-root swept wing built on Hill's isoclinic principle. D. Williams. R. & M. 2870. (1956).

This note shows how the Hill Aero-isoclinic Principle works out in practice for a swept wing, fixed at the root and having straight flexural and inertia axes. The conditions assumed are readily represented in a wind-tunnel model and experiments by Lambourne show good agreement with theory.—(1.10.1.2).

Testing and Instruments

A wind-tunnel technique for flutter investigations on swept wings with body freedoms. P. F. Jordan and F. Smith. R. & M. 2893. (1955).

A technique is described which has been developed for wind tunnel tests on wing-flutter models with the body freedoms. A half-span wing model is used, attached to a rigid body; longitudinal stability is ensured, and the body-mass parameters are reduced to small values by an appropriate arrangement of supporting springs. The ease of parameter variations makes the wind tunnel rig suitable for systematic investigations.—(1.12.1.1 × 2).

Methods of manufacture of wire resistance strain gauges. I. G. Scott. A.R.L. Note S.M. 226. (*May* 1956).

A survey is made of the various methods used for the manufacture of wire resistance strain gauges, both in this country and in the United Kingdom.—(1.12.6.2).

AEROELASTICITY

See also Testing and Instruments
Structures—Loads

Wind tunnel tests on antisymmetric flutter of a delta wing with rolling body freedom. D. R. Gaukroger and D. Nixon. C. P. 259. (1956).

Wind tunnel tests on a half span model to determine the anti-symmetric flutter characteristics of a delta wing are described. The model had a leading edge sweepback of 45° and a tip chord $\frac{1}{16}$th of the root chord. The effect of fuselage rolling moment of inertia on critical flutter speed and frequency was investigated.—(2).

Safeguards against flutter of airplanes. G. De Vries. N.A.C.A. T.M. 1423. (*August* 1956).

Practical rules are given, derived both from theory and from experience, intended to guide the aeronautical engineer in the design of flutter-free aeroplanes. Rules applicable to the wing, the ailerons, the flaps, tabs, tail surfaces, and fuselage are discussed.—(2).

AIRCRAFT

See Flight Testing

ELECTRONICS

An electronic analogue computer. D. E. Hatton and J. R. Ward. A.C.A. Report 57.

An Electronic Analogue Computor is described which has been designed and built in the Department of Aeronautics, University of Sydney. The basic theory of the machine solution of ordinary differential equations is summarised and an analysis is made of the theoretical performance of electronic analogue type computors. Several representative problems have been solved to illustrate the computational technique, and the theoretical and machine solutions are compared to indicate the overall accuracy which has been achieved.—(11 × 22).

An arbitrary function generator for use with an electronic analogue computer. J R. Ward. A.R.L. Note I. 58. (*March* 1956).

The instrument described has been developed for the generation of arbitrary functions either of time or of a variable voltage in an electronic analogue computor.—(11).

FLIGHT TESTING

V-g records from Vampire aircraft (*March* 1951-*October* 1951). *E. M. Owen and J. R. Heath-Smith. R. & M.* 2963. (1956).

Four hundred and sixty-one *V-g* records covering 923 flying hours were taken from Vampire aircraft operating in England and Germany during the period March to October 1951. *V-g* boundaries expected to be exceeded once in 30, 100 and 300 hours are estimated, special consideration being given to aircraft engaged on ground-attack duties.—(13.2).

Saunders-Roe Princess flying boat G-ALUN air and water handling tests. C. P. 257. (1955).—(13.2 × 3.10).

Comparison of flight and wind-tunnel measurements of high-speed-airplane stability and control characteristics. W. C. Williams et al. N.A.C.A. T.N. 3859. (*August* 1956).

Comparisons of some wind tunnel- and flight-measured values of stability and control characteristics have been made for three swept wing aeroplanes to show the agreement in trends and values of the data. In general, agreement of the data was good; however, where differences in the data were shown, generally they could be attributed either to specific geometric discrepancies between model and aeroplane or to model test techniques. Some suggestions are included for improving correlation of wind tunnel and flight data and for analysis of the wind tunnel data.—(13.2).

FUELS AND LUBRICANTS

Properties of aircraft fuels. H. C. Barnett and R. R. Hibbard. N.A.C.A. T.N. 3276. (*August* 1956).

Recent production jet fuels are surveyed and the ranges of fuel properties which can be encountered for each grade of fuel are shown. The effect of temperature and pressure on many of these properties is given. In the future fuel oils may be used in jet aircraft; and, therefore, these fuels have also been treated.—(14).

HYDRODYNAMICS

The full-scale hydrodynamic performance of a large four-engined flying boat at overload in calm water and swell. J. A. Hamilton and R. V. Gigg. R. & M. 2898. (1956).

Tests have been made on a large four-engined flying boat (Solent Mk. 3) to determine the hydrodynamic performance

in sheltered water and in open-sea swells. The sheltered water characteristics were investigated over a range of weights between 72,000 and 84,000 lb. The performance in swell covered weights up to 82,000 lb., and swell heights up to 5 feet.—(17).

The hydrodynamic characteristics of modified rectangular flat plates having aspect ratios of 1·00, 0·25 and 0·125 and operating near a free water surface. K. L. Wadlin et al. N.A.C.A. Report 1246. (1955).

Results are presented from an investigation of the hydrodynamic forces and moments acting on modified rectangular flat plates with aspect ratios of 1·00, 0·25, and 0·125 mounted on a single strut and operating near the free water surface. A simplified method of obtaining the lift characteristics in unseparated flow at large depths is presented. The experimental effects of changing the angle of attack, depth of submersion, and aspect ratio are presented. The effects of cavitation and two types of high-angle leading edge separation are also presented.—(17.2).

MATERIALS

A method for assessing the corrosion of iron in soils. Part 2. Preliminary experiments. K. F. Lorking and P. F. Thompson. A.R.L. Report Met. 15. (*March* 1956).

Potential measurements taken on platinum electrodes show that it is possible to deduce the depth of the boundary between aerated and de-aerated soil. From similar measurements on iron electrodes and by measuring the differential aeration currents generated between iron electrodes placed at various depths in the soil it is possible to determine the likelihood of corrosion occurring on steel, the distribution of corrosion on steel structures and the value of protective treatment on the steel. The work also shows that rainfall has a negligible influence on oxidising, but has a significant influence on differential aeration current.—(21.2.1).

The changes in hardness during fatigue tests on copper at 6000 *cycles/minute. R. B. Davies and J. Y. Mann. A.R.L. Report Met.* 16. (*May* 1956).

Annealed copper specimens, subjected to rotating cantilever fatigue tests increased in hardness during the early stages of tests at a rate depending upon the applied stress. However, the hardness of specimens tested under widely different stresses tended to converge towards a common range as cycling proceeded, and this hardness was much lower than the maximum hardness developed in a similar specimen fractured in static tension. Some observations of the development of cracks at early stages of fatigue tests are presented.—(21.2.2 × 31.2.2.5).

Sur la désorganisation et la restauration a froid de cristaux d'aluminium soumis a des traction faibles. J. Caisso. Pub. Sc. et Tech. 316. (1956).—(21.2.2).

Influence of hot-working conditions on high-temperature properties of a heat-resistant alloy. J. F. Ewing and J. W. Freeman. N.A.C.A. T.N. 3727. (*August* 1956).

The influence of various hot-working conditions on the high-temperature properties of a heat-resistant alloy was determined. The effects of hot-working on response to subsequent heat treatment were also studied. The working conditions varied were temperature, amount or reduction, and a combination of both. The evaluation of the effects of rolling was based on rupture and creep tests, hardness measurements, micro-structural examination, and lattice-parameter measurements.—(21.2.1).

Mechanical tests on specimens from large aluminum-alloy forgings. J. A. Miller and A. L. Albert. N.A.C.A. T.N. 3729. (*August* 1956).

Results of tensile and bend tests on specimens in the T6 condition from 12- by 12- by 24-inch hand forgings of 7075 (75S) and 2014 (14S) aluminium alloy are presented. Properties are given for specimens from various locations within the forgings as well as for specimens oriented in both the longitudinal and transverse directions.—(21.2.2).

Study of aluminum deformation by electron microscopy. A. P. Young et al. N.A.C.A. T.N. 3728. (*August* 1956).

The slip-line structure in a series of aluminium single crystals at various stages during deformation was examined in an electron microscope. The slip-line structure was also investigated in crystals strained after various degrees of prestraining. On the basis of the data from this study and from other investigations a theory is proposed for the deformation mechanism in aluminium crystals. The possible effects of short-range ordering on deformation modes are discussed.—(21.2.2).

Poisson's ratios and volume changes for plastically orthotropic material. E. Z. Stowell and R. A. Pride. N.A.C.A. T.N. 3736. (*August* 1956).

Measurements of Poisson's ratios have been made in three orthogonal directions on aluminium-alloy blocks in compression and on stainless-steel sheet in both tension and compression. These measurements show that there is no permanent plastic change in volume within the accuracy of observation. A method is suggested whereby a correlation may be effected between the measured individual values of the Poisson's ratios and the stress-strain curves for the material. Allowance must be made for the difference in the stress-strain curves in tension and compression; this difference, wherever it appears, is accompanied by significant changes in the Poisson's ratios.—(21.2).

Tensile properties of HK31XA-H24 magnesium-alloy sheet under rapid-heating conditions and constant elevated temperatures. T. W. Gibbs. N.A.C.A. T.N. 3742. (*August* 1956).

Specimens of HK31XA-H24 magnesium-alloy sheet from an experimental batch were heated to failure at nominal temperature rates from 0·2°F to 100°F per second under constant-load conditions. Rapid-heating yield and rupture stresses are presented and compared with the yield and ultimate stresses from elevated-temperature tensile stress-strain tests for ½-hour exposure. Linear temperature-rate parameters were used to correlate rapid-heating results by constructing master curves which can be used for predicting yield stresses and temperatures and for estimating rupture stresses and temperatures.—(21.2.2).

MATHEMATICS

See also ELECTRONICS

Opérateurs symboliques. H. Pailloux. Pub. Sc. et Tech. 317. (1956).

Présentation nouvelle de la notion d'opérateur linéaire pour les fonctions d'une ou de plusieurs variables. Propriétés de ces opérateurs. Application à la recherche de la solution générale d'une ou de plusieurs équations différentielles ou de dérivées partielles, linéaires et à coefficients constants, avec ou sans second membre. Equations de l'équilibre ou des petits mouvements d'un milieu élastique. Equations de Maxwell. Equations qui se décomposent. Lien entre les opérateurs à n variables et les équations aux dérivées partielles à $n + 1$ variables.—(22.1).

METEOROLOGY

Interim note on counting accelerometer results obtained from Viscount aircraft. N. E. Bacon. A.R.L. Note. S.M. 227. (*May* 1956).

Gust accelerometer data has been obtained from a Viscount aircraft operated by Trans-Australia Airlines between the five state capital cities of the Australian mainland. Records covering 346 hours were obtained from a Compound Counting Accelerometer and from these, data suitable for detailed analysis covered a period of 110 flying hours.—(24).

An investigation of vertical-wind-shear intensities from balloon soundings for application to airplane- and missile-response problems. H. B. Tolefson. N.A.C.A. T.N. 3732. (*July* 1956).

The daily upper-wind soundings taken at one station for a one-year period are analysed to obtain data on the vertical-wind-shear intensities and frequencies for use in aeroplane- and missile-response studies. The application of these results to the calculation of the normal response of a missile in vertical flight is also considered briefly.—(24).

CORRECTION

September 1956

In the September Reports, under "Mathematics," N.A.C.A. T.N. 1403, April 1956 "On the Instability of Methods for the Integration of Ordinary Differential Equations." H. Rutishauser, should have been T.M. 1403.

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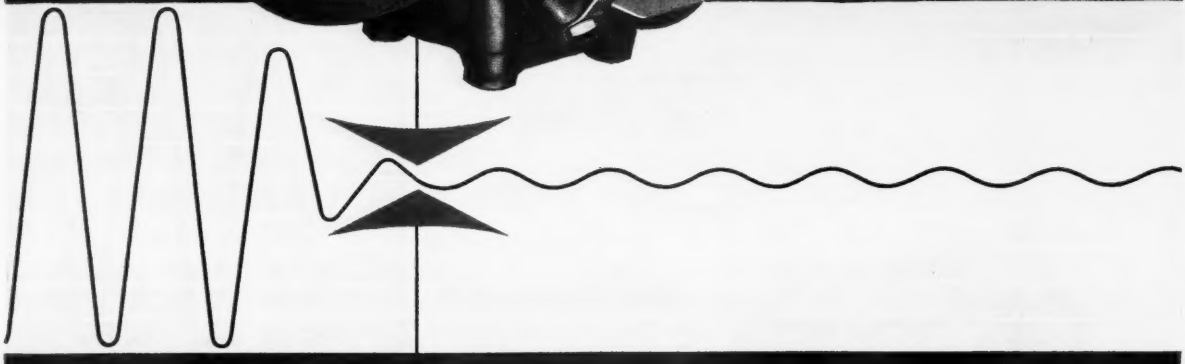

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